Masonry
Simplified

DALZELL · TOWNSEND
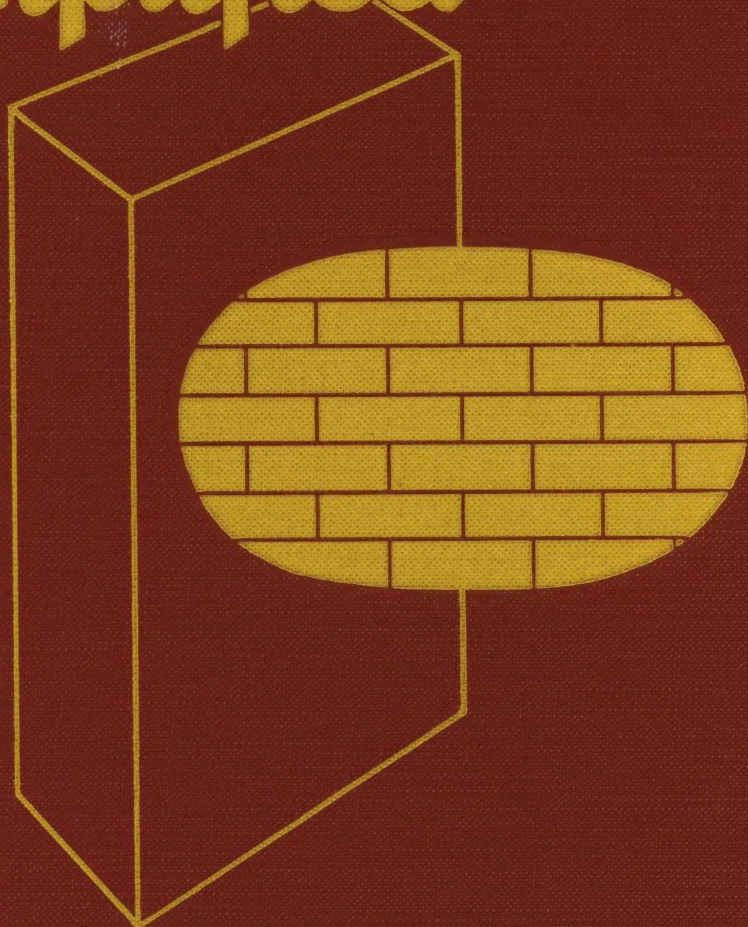
VOLUME II
PRACTICAL CONSTRUCTION
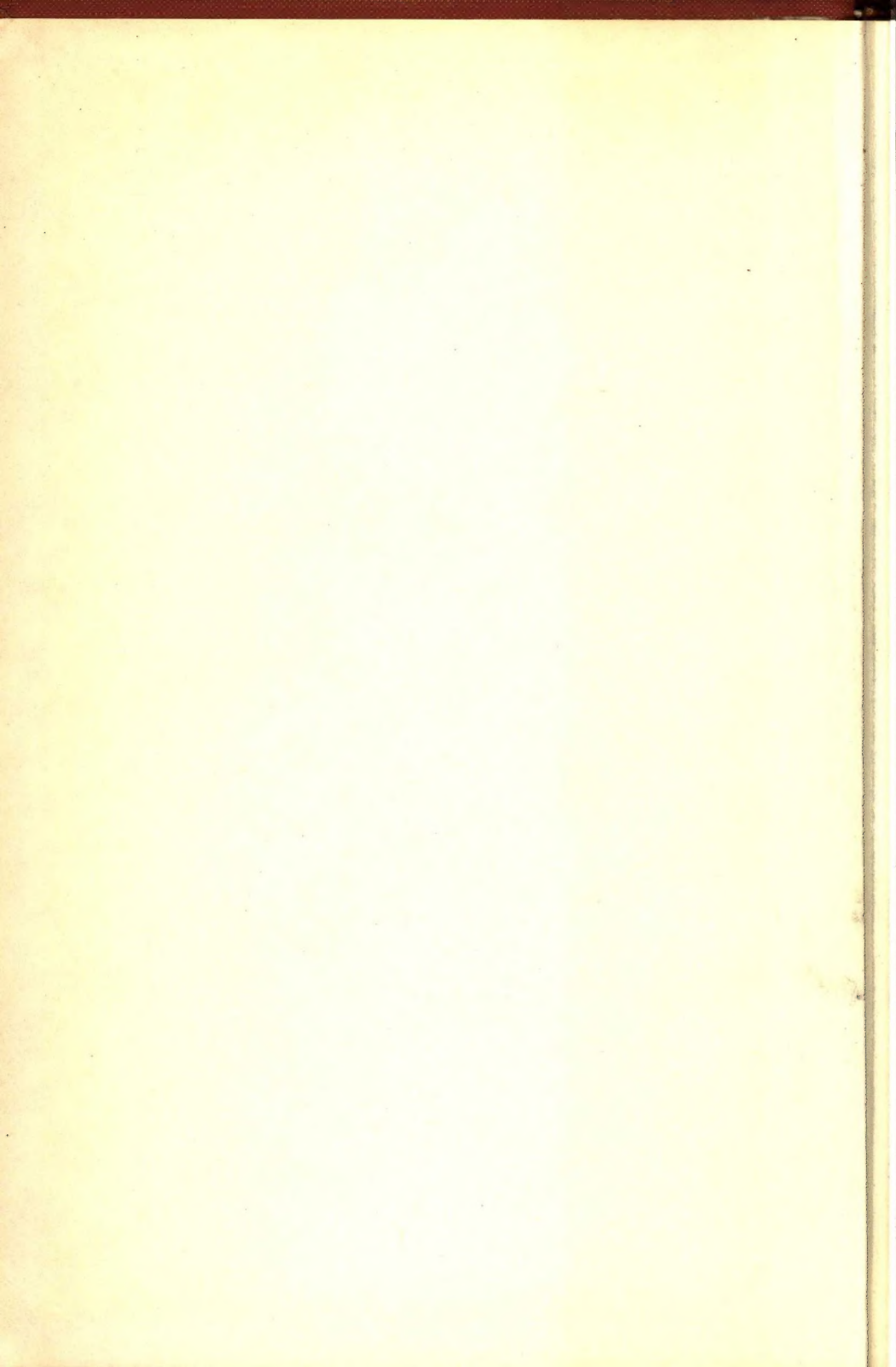
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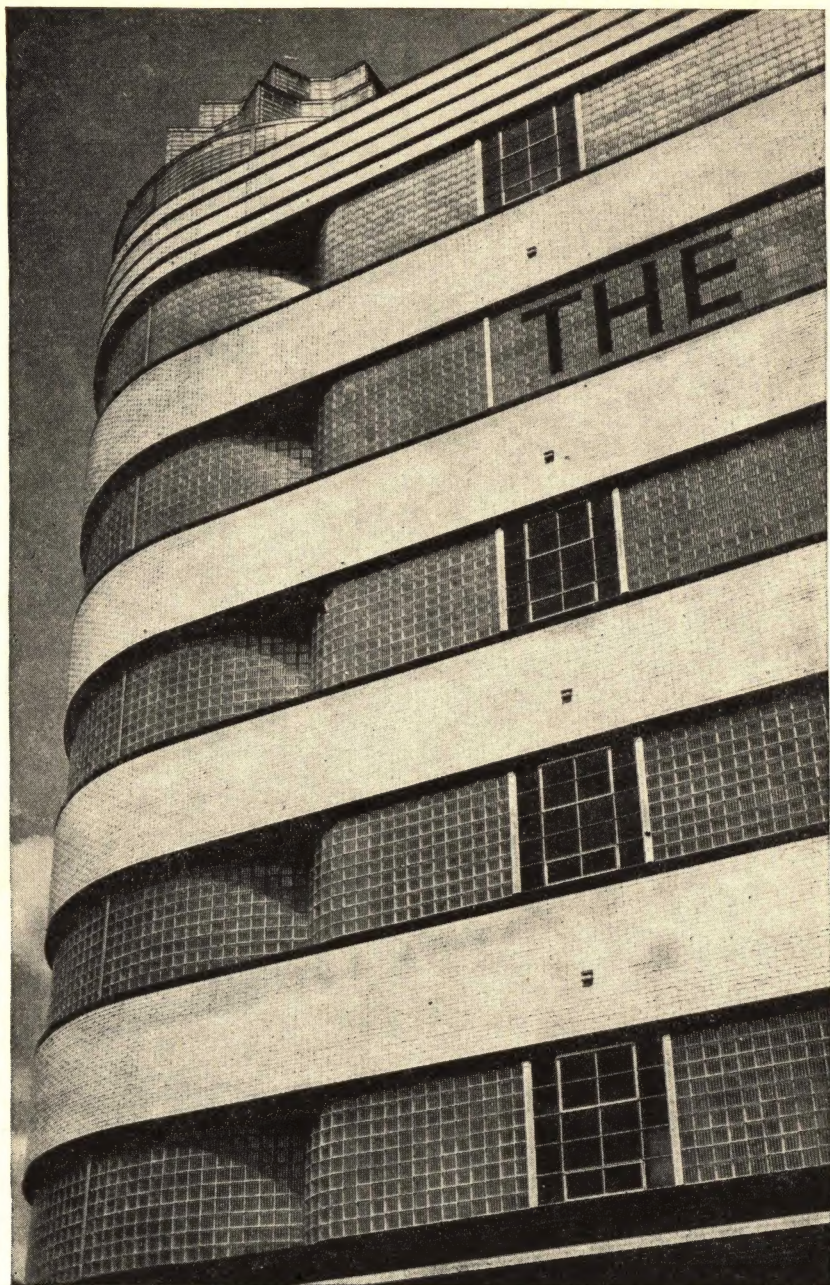
NEW MASONRY MATERIALS DEMAND NEW MASONRY TECHNIQUES
Courtesy of American Builder

MASONRY
SIMPLIFIED

Volume II
PRACTICAL CONSTRUCTION

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PREFACE

MASONRY SIMPLIFIED, *Volume II—Practical Construction* explains not only the *what* and *why* of masonry construction, but especially the *how*. It *applies* the fundamentals of masonry to every job that the mason must perform. Here is a book to fulfill the needs of apprentices, tradesmen, teachers, and laymen home mechanics.

J. Ralph Dalzell and Gilbert Townsend understand the many pitfalls that beset the average learner in acquiring a building trades skill. Their contributions to sound training in the building field are well known to hundreds of thousands who have used their books. This represents the latest in their long record of producing "teachable" and "learnable" texts. In selecting their material, the authors have called upon not only their own rich background but also the resources of all phases of the industry. As a result they have incorporated into this book those recommended practices that have become a standard in the field.

The authors make a completely new approach in presenting the principles of practical masonry construction. In showing piece-by-piece how masonry work is put together, they have discarded the conventional section-view drawings. Instead, they use dynamic *pictorial* illustrations that more clearly show each masonry component in its proper relation to allied parts. Even though a reader may not have a formal training in drafting, he can grasp at a glance each step in such procedures as building a wall or partition, pouring a foundation, constructing a fireplace, or erecting a chimney.

Masonry Simplified is not a collection of the unusual or unique. It is a presentation of those jobs and procedures that are both common and fundamental to the mason's training and background. These jobs and procedures are described in one-two-three order, and they precisely match on-the-job experiences.

Not only are necessary trade procedures explained, but sufficient related information is included to provide a comprehension of certain aspects of structural design. For example, the design and selection of

beams and columns, as well as the requirements of footing and foundation size, are matters usually handled by engineers and architects. But occasions do arise in which the help and advice of these men are unobtainable. This book, by including fundamental elements of design, enables the mason to determine loads, stresses, and other factors that govern the size and shape of beams and columns. The mathematics involved has been kept simple, and the solutions to all formulas have been given so that even with but little previous mathematical training the reader can grasp them.

Formwork too is a vital aspect of building that is closely related to the mason's job, although he may actually take little part in its construction. In most cases, formwork costs more than the concrete that fills it, and, furthermore, structurally sound walls, foundations, and footings of poured concrete depend upon adequate formwork. For such reasons it is especially important for the mason to understand what constitutes good formwork.

Because recent trends toward decentralization of population and modernization of farms have thrown emphasis on the problem of sewage disposal in rural areas, the text includes a chapter on the proper design and construction of efficient septic systems.

For the enlarged Second Edition of this book, two new chapters have been added. There is a detailed discussion on how to build with brick having a thickness of 6 inches. By using these units substantial savings can be effected in the construction of one-story buildings. The final chapter was prepared to meet the needs of readers who are searching for information on how to maintain masonry in good condition and how to improve its appearance. Among the topics discussed are the treatment of efflorescence, stain removal, crack repair, tuckpointing, waterproofing, and the application of several kinds of masonry paints.

This book outlines concepts of masonry procedures that should be helpful to builders, contractors, architects, and all building tradesmen. It answers the exacting requirements for formal instruction of vocational students and apprentices; and it provides how-to-do-it directions for farmers and homeowners who are unable to obtain the services of a mason and find it necessary to do their own work.

THE PUBLISHERS

ACKNOWLEDGMENTS

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MODERN ARCHITECTURAL DESIGN UTILIZES MASONRY
WALLS IN FACTORY, OFFICE, AND HOME
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CHAPTER I

Building Forms for Concrete

QUESTIONS CHAPTER I WILL ANSWER FOR YOU

1. *What are some of the requirements which good formwork must fulfill?*
2. *What are the kinds of formwork and what purpose does each serve?*
3. *What variety of lumber is considered best for formwork and what are some of the specifications it must meet in order to be found acceptable?*
4. *What fastenings are used in formwork construction and how does this affect costs?*
5. *How is the correct level for concrete determined in the formwork before the pouring is started?*

INTRODUCTION TO CHAPTER I

No matter from what point of view formwork is considered, it is every bit as important and just as essential as the concrete for which it is built. The adaptability and versatility of concrete cannot be denied. Its use in structures of all kinds is an accepted convenience. But a fact seldom given due consideration is that the very nature of concrete which makes it of such great value in construction work of all kinds is dependent solely on formwork. In other words, the extensive use to which concrete is put in modern building would not be possible without formwork.

Considered from an economical standpoint, formwork is even more important than concrete. It is not unusual for formwork costs to exceed those of the concrete. The more intricate the foundation or other structure of concrete, the more difficult the formwork will be to construct. Under these conditions, the cost of the forms may rise but the cost of the concrete will remain relatively constant because approximately the same quantity of concrete will be used in both cases. In presenting such a considerable item of expense in building, the construction and use of formwork offers a challenge to the contractor's ingenuity. However, no saving of any kind should ever be attempted which might result in inferior formwork (and therefore inferior concrete).

Structurally, formwork is important because of the great density or weight of the concrete it must contain. Until the plastic mass has had a chance to set or harden and become self-supporting, the formwork is responsible for holding the concrete in the shape desired for it. Since a cubic foot of concrete will weigh approximately 150 pounds, the tremendous strength necessary for a foundation formwork, or forms for a similar structure of any size, can be readily appreciated. Because the ultimate strength of any concrete structure is partially but directly dependent upon its formwork, the importance of this phase of masonry cannot be emphasized too much.

The skill involved in the construction of formwork varies with the degree of complexity. A simple, square foundation will not require very elaborate formwork. But if the straight lines of the foundation are broken by ells, bay windows, areaways, outside basement steps, etc., construction of the formwork will be much more difficult and will call for correspondingly greater skill and experience. However, simple formwork requires just as much care and attention to details as the complex. Both types must be constructed so that the finished concrete has every chance to develop properly.

These three points should serve to stress the importance of formwork and its effect on concrete. If these points are kept in mind as the theory of concrete formwork is given, the kinds of formwork described, design of formwork discussed, and finally, the construction of formwork shown, you will have a thorough understanding of the basic principles involved and will be well equipped to apply these principles on the job.

IMPORTANCE OF FORMWORK

The successful employment of plain or reinforced concrete, whether for structural members in various kinds of buildings or for any one of hundreds of other possible uses, depends to a great extent upon the care with which the necessary formwork has been constructed. This is an important fact and should be kept in mind.

Actually, the construction of formwork is not the mason's job. Usually, most formwork and especially the more complicated kind is erected by carpenters. This is the only policy when carpenters are available at the required time. However, for small jobs where simple formwork can be used, masons can and do attend to the formwork as well as to the mixing and pouring of the concrete. It is advisable, therefore, that beginning masons know some of the basic principles involved in the construction of satisfactory formwork.

From the standpoint of structural details, or what can be called design, there are many ways in which the formwork for any specific job can be constructed. Perhaps no two carpenters or masons would construct the forms for a given job in the same way. The manner in which forms are constructed makes little difference so long as they do the job and come within reasonable cost limits. The purpose of this chapter is to illustrate and explain only typical examples of formwork most generally required for residences, farm buildings, small stores, garages, and other structures. This formwork falls into two classifications—tailor-made or unit—and the construction and application of each is carefully illustrated and described.

THEORY OF CONCRETE FORMWORK

Before starting a study of the typical kinds, design, construction, and placing of formwork, it is well to understand the theory of formwork in general.

Purpose of Formwork. Among the many advantages of concrete when used as a structural material is its plastic quality before it hardens into a rocklike mass. This allows it to be formed into any shape desired. It can be made to serve in the form of beams, columns, foundations, floors, footings, lintels, unit masonry, and innumerable other items, all of great value in the construction of any kind of building. However, newly mixed concrete is fluid and will not hold any shape by itself. If poured from a concrete mixer directly on the ground, it slumps into a flattened mass before it has a chance to harden and hold its shape. Thus, if a cube of concrete is desired, some sort of mold or formwork must be provided into which the wet concrete can be poured. If the formwork is strong enough to hold the wet and heavy concrete in the required shape until it has hardened or set, it will always remain in the shape of the cube. In other words, if concrete is poured into formwork and held securely in place until it hardens and gains strength, it will always remain in that shape after the formwork has been removed. Therefore, the purpose of formwork is to hold wet concrete securely in any desired shape until the concrete has hardened and gained strength. Once hardening and strength have been attained, the formwork surrounding the concrete can be removed.

If a concrete foundation is desired, formwork must be constructed to hold the wet concrete in place in the same way as for the cube. The formwork must be constructed so that the poured concrete will take the shape of the desired foundation. The same is true of footings, beams, columns, floors, and such miscellaneous items as fence posts, flower boxes, machine foundations, curbs, steps, etc.

Requirements of Formwork. When planning and building formwork that is general in nature, there are several important requirements to be kept in mind. Other requirements more specific in nature are discussed at the proper places in this chapter.

FORMWORK MUST BE STRONG. This requirement can be appreciated when it is realized that concrete weighs approximately 150 pounds

per cubic foot. This mass can be visualized better by referring to Fig. 1 which shows a section view of a concrete footing and a concrete foundation. Note the formwork necessary to hold the wet foundation concrete in place. This particular foundation is 12″ wide and 6′ 0″ high. A part of this foundation 1′ 0″ long would consist of six cubic feet. This section is illustrated in (A) of Fig. 1, where six cubes are shown.
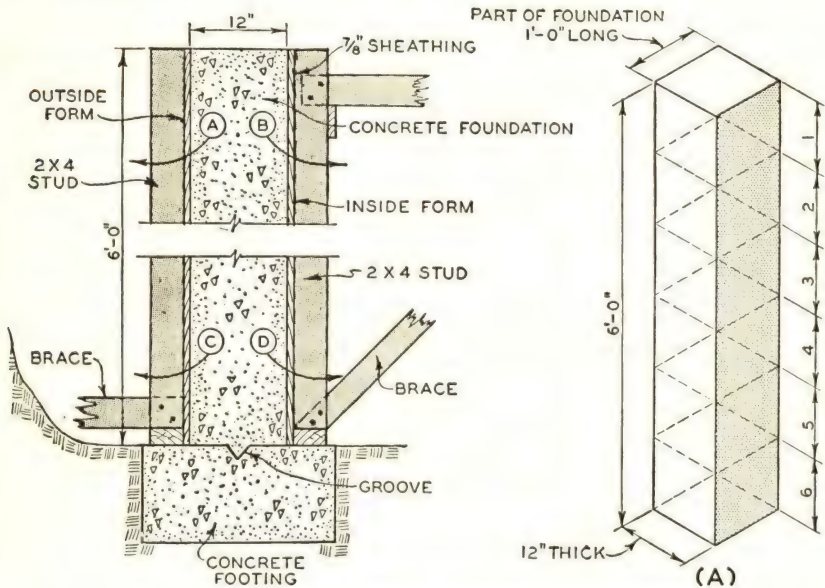
Fig. 1. Cross Section of Concrete Foundation Showing Formwork

If the weight of this small section of foundation is calculated, it will be found to be 900 pounds. This considerable weight of wet concrete, when in the formwork as shown in the section drawing of Fig. 1, exerts a sideward force indicated by arrows *A, B, C,* and *D* as well as pressure directly downward on the footing. When a foundation many feet long is considered, it can readily be seen that there is a great force created by the wet concrete tending to push the formwork apart as indicated by the arrows in Fig. 1. This force must be overcome by the strength of the formwork.

Resistance to the outward push created by the concrete is achieved through adequate bracing and by the use of wires which extend through the concrete and are fastened to the outer sides of the formwork.

There are several other ways of resisting the weight of the concrete in addition to bracing and wires. These methods will be discussed in succeeding pages of this chapter. At this point, the most important consideration is to understand why formwork must be strong.

FORMWORK MUST BE SMOOTH. In order that the surfaces of foundations and all other concrete items will be smooth, the interior surfaces of formwork must be kept smooth. This is especially true where concrete surfaces such as basement walls are visible. Once the formwork is removed from, for example, a foundation, the surfaces of the concrete will show every mark that was on the formwork. Even the graining in the boards of the formwork will be visible. If a board with a knot in it was used in the formwork, the impression of the knot will be clearly visible in the surface of the concrete. If a formwork board is rough, the finished concrete surface will be rough too. If there are sizable cracks between formwork boards, these cracks will appear as projections in the concrete. A smooth concrete wall surface can only be accomplished by the use of smooth formwork.

FORMWORK MUST BE TRUE. All formwork, unless actually required otherwise, must be true. For example, the side formwork for footings and foundations must be absolutely vertical. This can be accomplished only through careful use of the plumb rule or level when the formwork is being constructed. When formwork has been completed, it should be rechecked to make certain that it is true.

Unless the various boards used in building the formwork, as shown in Fig. 1, are jointed tightly, a crack will result. In addition to resulting in a poor appearance for the finished structure, cracks in the formwork allow the cement paste to escape. When this happens, the concrete becomes porous and of low strength. If too much cement paste escapes, the concrete will be an absolute failure.

In like manner, all other joints in formwork must be made tight in order to prevent the escape of the cement paste. Before concrete is poured into the formwork, the formwork should be inspected carefully to make certain there are no cracks or other openings through which the cement paste could escape.

FORMWORK MUST BE EASILY REMOVABLE. Formwork should be constructed so that it can be removed easily without damaging it during the process. To do this, two-headed nails are used in the assembly of

the formwork. Such nails actually have two heads at the hammer end, the lower about ¼″ to ½″ below the upper. A nail of this kind can be driven in only to the lower head so that the portion between the heads is left protruding. When the forms are stripped, the claw of the hammer is placed between the two heads and the nail is easily withdrawn.

Screws sometimes are used in erecting formwork because they can be removed so easily once the concrete has hardened.

FORMWORK MUST BE PLANNED. When pipes such as sewers must run through a foundation at a point below the grade level, special care must be taken to provide space for them before the concrete is poured. Usually, a section of the pipe to be used is put into the formwork at the correct place and the concrete poured around it. When the concrete has hardened, the pipe is not removed but connected as a part of the system. This makes a waterproof joint between the concrete and the pipe.

When steam lines or plumbing pipes pass through the foundation above grade or away from any possible water, pieces of sheet iron rolled to a diameter slightly larger than the pipes can be used as a form. When the concrete hardens, the sheet metal is removed, leaving the necessary passage through the foundation.

Occasionally, the earth at the sides of excavations for basements, etc., may be firm enough to be used instead of outer formwork. In such cases, only the inner formwork is necessary. However, several important conditions must be considered if the side of the excavation is to be used in place of wooden formwork.

If the earth is dry, for example, it may take moisture from the wet concrete with the result that the concrete, once it has set, will be weak and porous. If the earth is wet and muddy, the mud will sometimes mix with the concrete and thus weaken it. For these reasons, the sides of the excavation should be carefully inspected before it is decided to use them as formwork.

When earth forms are used, care should be observed during the pouring and tamping of the concrete to guard against knocking down of pieces of earth from the sides of the excavation. This earth, falling into the concrete, will cause weak and porous spots in the foundation. It is safer always, and more satisfactory, to use regular formwork for both sides of the foundation.

As was stated at the beginning of the chapter, good concrete work can be made only through the use of good formwork. In the past, some masons—especially beginners—had a tendency to construct formwork carelessly. This is poor policy no matter what type of concrete work is required. Readers are urged to make a habit of constructing all formwork carefully so that the concrete will not only serve its purpose and meet requirements generally, but will look well too. Then, and only then, can any pride be taken in the work done.

Formwork Material. The greater amount of all concrete formwork is made of lumber. Wood works to the best advantage in most cases and is an easy material to handle. This chapter is concerned only with formwork made of lumber.

Metal formwork can be used to advantage when the work involved is to be repeated many times. Metal formwork of various types and designs can be purchased. The initial cost may often be high but repeated use makes such expense worth while.

Cost of Formwork. Good formwork may sometimes cost more than the concrete for a particular job. However, no cheapening of formwork should ever be attempted because such efforts almost invariably result in inferior concrete work. For this reason, it is false economy to skimp on the cost of the formwork.

The cost of formwork should be determined from local sources for each job since material and labor charges vary considerably from place to place and from time to time. The data in Table I (which applies to

TABLE I. COST OF FOUNDATION FORMWORK
PER SQUARE FOOT OF CONTACT AREA

CONSTRUCTION ITEM	COST FACTOR
Sheathing 7/8" x 8"	1.2
Studs 2 x 4	.93
Wire	.02
Eight-penny nails	.04
Twenty-penny nails	.01
Sheathing labor	.03
Stud labor	.03
Removal of form labor	.02
Time reworking form lumber	.006

NOTE—If formwork is to be salvaged for other uses, deduct .96 and .87 from the sheathing and studding cost factors respectively.

formwork such as shown in Fig. 18) will be helpful in approximating the material and labor required for almost any job.

In order to understand how this table is used, suppose the cost is to be estimated for the formwork of a foundation 9″ thick, 12′ 0″ in height, and 30′ 0″ long. The area for one side of the wall is 12′ × 30′ or 360 square feet. Formwork for two sides is required so 720 square feet of formwork is needed.

Multiply each of the items in Table I by 720 to find the total quantity of different materials and labor needed, then multiply each of the totals by the local price of each material or wage. The sum, without any extras such as profit or overhead, will be the actual cost of the formwork. If the lumber in the formwork can be used for other purposes after it has been removed, multiply the item salvage constant by 720 and the price for that particular size of lumber, then deduct the amount from the cost previously calculated.

KINDS OF FORMWORK

There are many ways in which the formwork for various concrete jobs can be constructed. Many kinds of formwork are illustrated and explained in this chapter but it is pointed out that the examples and illustrations presented here are typical.

Footing Formwork. Footings are required under foundations, chimneys, columns, pilasters, etc. Side forms are necessary for good work unless the earth is firm enough to stand erect at the sides of the footing excavations. It is not often that suitable earth is encountered; therefore formwork is usually necessary. It should be pointed out again that poorly made footings do not properly serve their purpose. The only way in which to be assured of good footings is to use well-constructed formwork.

Fig. 2 illustrates typical formwork for foundation footings. This formwork is for a footing which must be 10″ deep and 20″ wide. Note how the vertical side forms are held in place by stakes placed at frequent intervals. The stakes in turn are held upright by other stakes and braces. The stakes and braces should be at frequent intervals to prevent the side forms from bowing out as the concrete is placed and tamped. Spacers should be used at frequent intervals also to help prevent the side forms from leaning toward the center of the footing.

Foundation footings should always have some form of groove or key as shown in Fig. 1. This groove serves to lock the foundation in
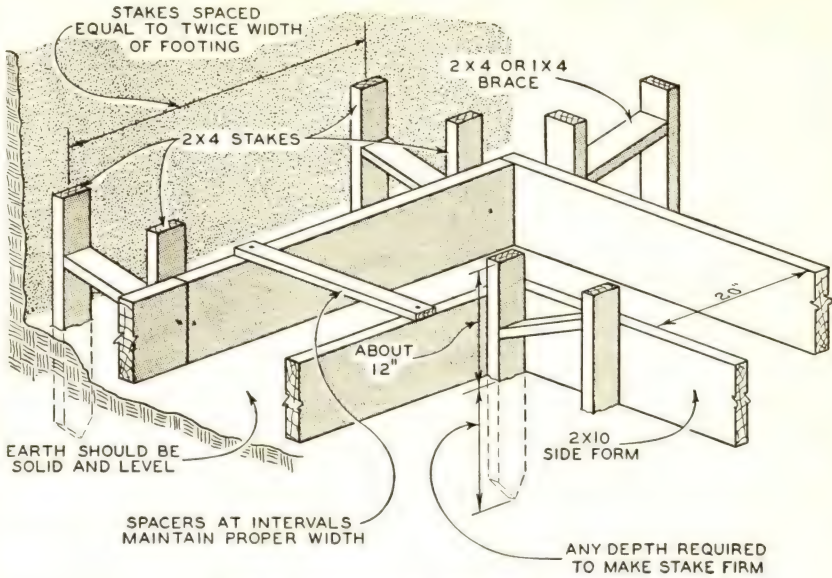
Fig. 2. Formwork as Used for Footings

place. Provisions for molding such a groove into the footing must be made prior to the time the concrete is poured. Fig. 3 illustrates a typical method for providing this necessary formwork. It can be seen that the groove (sometimes called an anchor) form is held in place by the spacers. When the concrete is poured, it surrounds the groove form
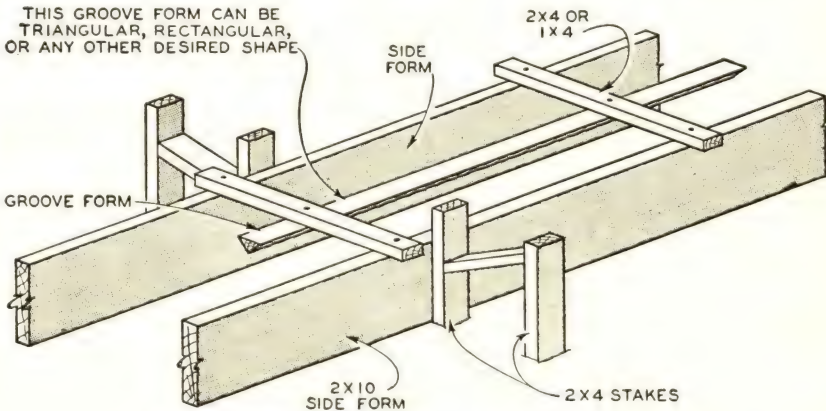
Fig. 3. Footing Formwork with Form for Anchor Groove in Place

SIDE FORM BOARDS

SIDE FORM BOARD

2 X 4 STAKE

2 X 4 STAKE

2 X 4 HANGER

2 X 2 OR 1 X 2 SPACER

2 X 4

2 X 4 BRACE

2 X 4 STAKE

2 X 4 STAKE

2 X 4 BRACE

SIDE FORM BOARD

2 X 4

X

N

Y

B

C

M

D

A

E

PICTORIAL VIEW

FOUNDATION

STEP

FOOTING

C

D

B

A

E
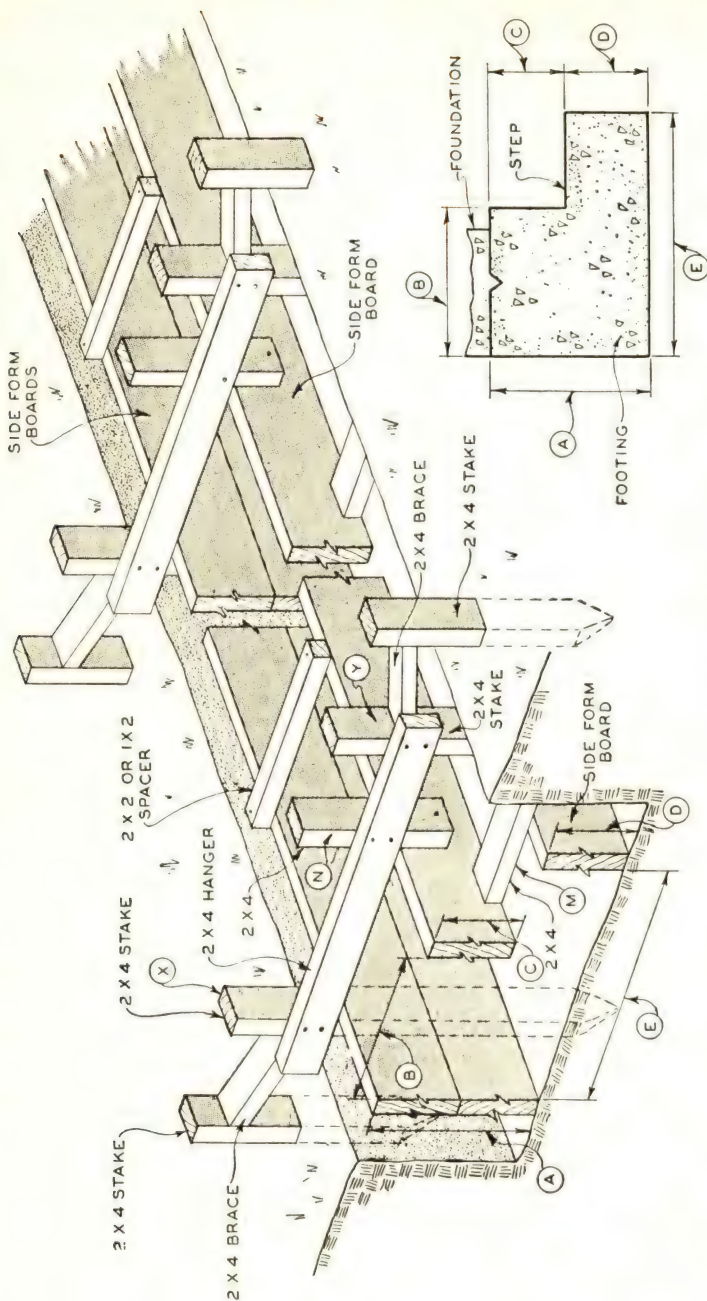
SECTION VIEW

Fig. 4. Formwork for Stepped-Down Footing on Property Line

on the two lower sides. When the groove form is removed after the concrete has set, there is a permanent key in the concrete.

Special kinds of footings are required when the building they support touches a property line. An example of this type of footing is shown in the section view of Fig. 4. The formwork required for such a footing is shown in the pictorial view of the same illustration. The parts of the footing designated by the letters A, B, C, D, etc., in the section view correspond to those parts designated by the same letters in the pictorial view. This kind of footing cannot under any circumstances be poured without well-made formwork.

The form for side A of the footing is made similar to the formwork shown in Fig. 2 except that it is higher and composed of more than one plank in addition to its having much longer stakes. The form for side D is just like the side forms in Fig. 2. To provide for the recessed or stepped side C, a plank is hung from a 2 x 4 hanger which is held in place by stakes such as those at X and Y. A short piece of 2 x 4, N, is nailed to the hanger and the plank for the side form nailed to it in turn. Another short piece of 2 x 4, M, helps hold this side form in place. Hangers and such pieces as M and N must be used at frequent intervals. Supporting braces, stakes, and spacers are similar to those shown in Fig. 2. Special care in placing the concrete in such forms is necessary to prevent their displacement if struck with wheelbarrows or shovels. Such blows could easily knock the formwork out of plumb.

Another special kind of foundation footing is shown in the section view of Fig. 5. The sides indicated by the letters A, B, C, etc., in the section view correspond to like sides indicated by the same letters in the pictorial view.

For this type of footing, the bottom part must be poured first using the same formwork as shown in Figs. 2 and 3. When the concrete has set and is fairly hard, earth is backfilled around it and the formwork for the top part constructed as illustrated by the pictorial view in Fig. 5. Short pieces of 2 x 4, M and N, are nailed to the side forms at frequent intervals. These side form pieces are held in the proper position by braces and stakes. Note that the braces are crossed so they can be nailed to both tops and bottoms of the pieces M and N. Spacers are necessary as with all formwork for footings.

The footings for chimneys, when they are part of an exterior wall,
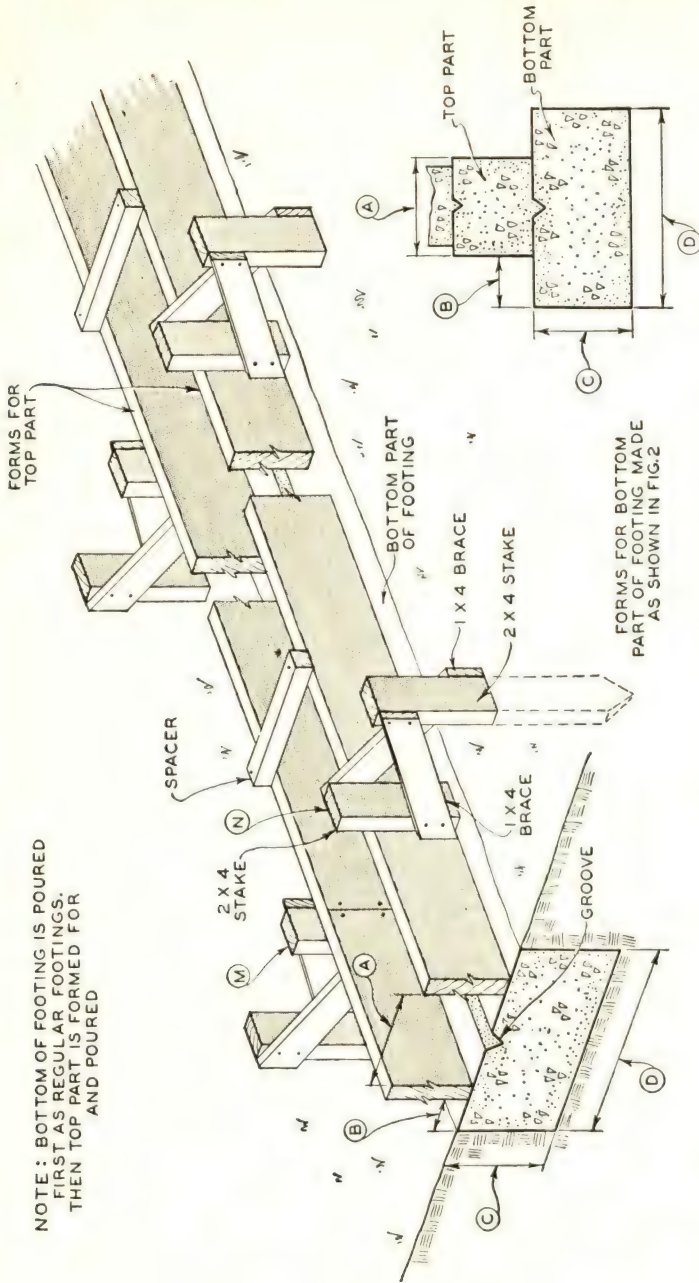
Fig. 5. Formwork for Top Part of Stepped-Down Footing

can be made by a simple widening of the foundation footing as shown
in Fig. 6. The regular footing formwork is constructed as described
for Figs. 2 and 3. The formwork for the widened section is constructed
in a similar manner, making certain that the side forms are held and
braced properly in their correct position. The widened portion of the
footing, *ABCD*, need not have the center groove or key but that part
of the footing not within the widened area must have the usual groove.

The formwork shown in Fig. 6 can be used also to make footings
for all types of pilasters.
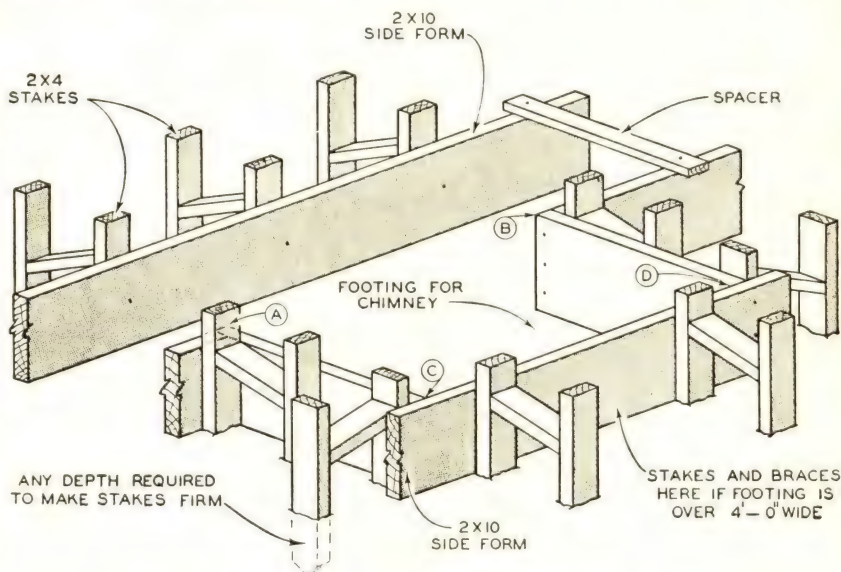
Fig. 6. Formwork for Combined Wall and Chimney Footing

A typical example of the simple formwork necessary for columns
or chimneys which are not part of the exterior wall of a building is
shown in Fig. 7. This formwork is boxlike in appearance and is held
in place and braced as indicated. For small footings not over 2' 0"
square usually two, but never more than four, stakes will be enough.
If the formwork is not more than 12" in height, the stakes seldom need
be braced. For higher formwork, especially where more than one plank
is used in the side form, two stakes to a corner should be used and
these should be well braced. If such footings are 4' 0" or more on a
side, stakes should be spaced about 2' 0" apart along the sides in

addition to the two at each corner. For larger and higher footings, the additional stakes are required because of the weight of the concrete and its tendency to push outward and bow the formwork.

Foundation Formwork.   There are two general kinds of formwork used in pouring concrete foundations. One kind is the unit form which is made in standard sizes or shapes so that it can be used on one job after another. The other kind is what might be called tailor made and is constructed from lumber for each job; then it is dismantled and the lumber used elsewhere once the concrete has hardened.

USE TWO-HEADED NAILS SO FORMS CAN
BE EASILY TAKEN APART. IF TWO-HEADED
NAILS ARE NOT AVAILABLE, REGULAR NAILS CAN
BE DRIVEN IN SO THEIR HEADS CAN BE
GRIPPED BY A CLAW HAMMER

STAKES ON TWO OR MORE SIDES
AS REQUIRED CAN BE BRACED
IF NECESSARY BY THE SAME
PROCESS AS SHOWN IN FIG. 2

2 X 10 - 2 X 8 - 2 X 6 ETC.
AS REQUIRED

USE ADDITIONAL STAKES FOR
FOOTINGS OVER 2'-0" LONG
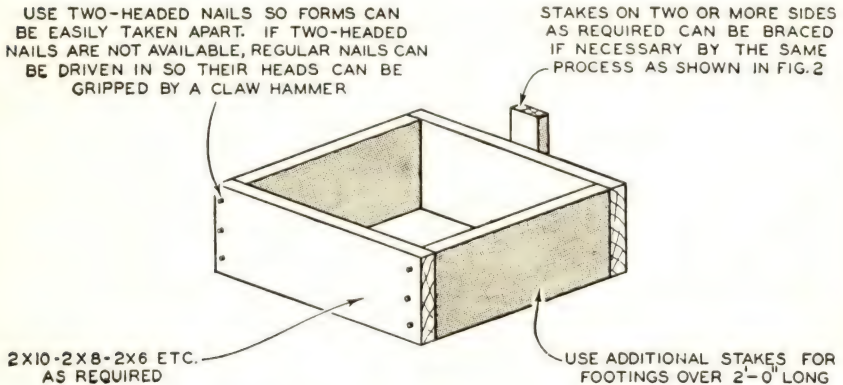
Fig. 7. Formwork for a Column Footing

UNIT FORMS. Unit forms, as the name implies, are made up into units of varying sizes, usually in even multiples of two feet. Typical forms of this kind are shown in Fig. 8. It will be noted that in this illustration, one of the units is 4' 0" x 4' 0", while the other is 2' 0" x 4' 0". Other typical sizes for unit forms are as follows:

6' 0" long by 4' 0" high	12' 0" long by 4' 0" high
6' 0" long by 6' 0" high	12' 0" long by 6' 0" high
8' 0" long by 4' 0" high	12' 0" long by 8' 0" high
4' 0" long by 8' 0" high	6' 0" long by 8' 0" high

In fact, in order to suit the sizes of foundations a mason most generally pours, unit forms can be made in practically any combination of dimensions.

When a mason does a great amount of foundation work, the use of unit forms is an economical practice since they can be used almost
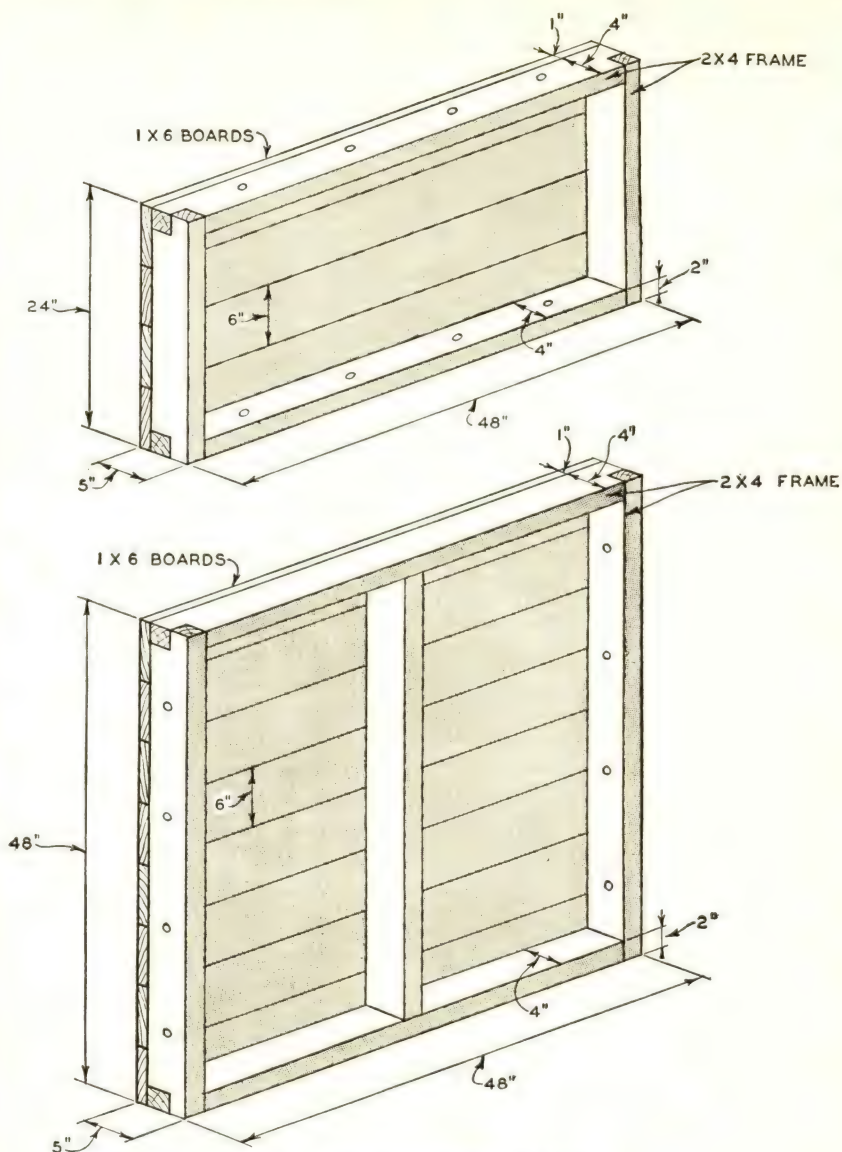
Fig. 8. Standard Sizes for Unit Forms

any number of times if they are well made and adequately maintained. The economy obtained through their use is due to the saving of lumber and the labor cost in construction time. The construction time

saved is probably the greater economy because unit forms can be made ready for concrete on the ordinary foundation job in a few hours. The construction of the so-called tailor-made formwork may require several days.

Fig. 9 shows a group of the 4′ 0″ x 4′ 0″ forms set up in place for a typical foundation. Note that the boards in the forms run horizontally. This is usually the best practice because the board marks
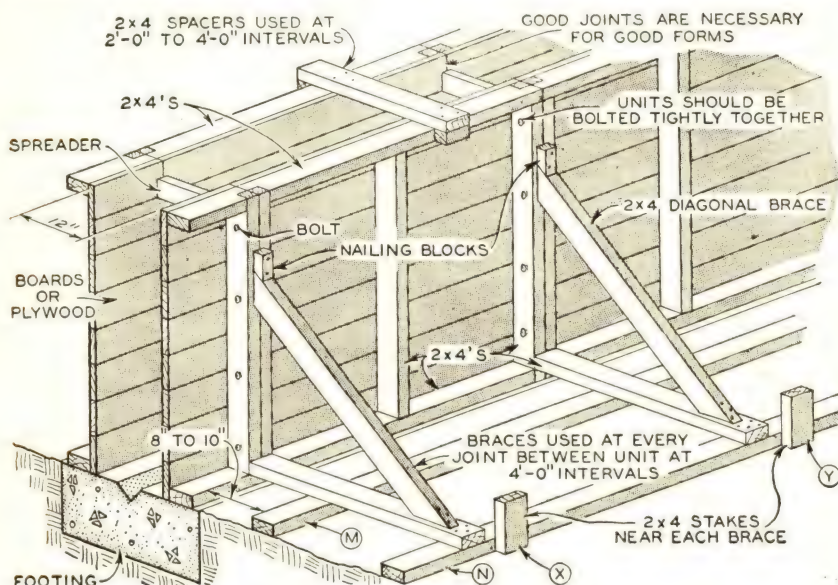
Fig. 9. Unit Forms for Foundation in Place on Footing

on the hardened concrete will run horizontally just as most boards do when used in buildings.

These forms are supported by 2 x 4 braces at intervals which should not be more than 4′ 0″ apart for foundations up to 6′ 0″ in height and not more than 2′ 0″ apart for higher foundations. Note the nailing block used to insure a good, solid meeting of the brace and the studding of the forms. The 2 x 4 braces are supported by other 2 x 4′s laid flat atop 2 x 4 runners which are laid flat on the ground. The outer runner must be held in place by 2 x 4 stakes driven at not more than 4′ 0″ intervals for low foundations and not more than 2′ 0″ intervals for high foundations. The forms can be nailed together but it is a

better practice to bolt them together as suggested in Fig. 9. Both sides of the forms (that is, the inner and outer forms) should be braced. At the tops of the forms, spacers are necessary as a means of preventing the forms being spread apart by the weight of the concrete. Spreaders are used to prevent the forms from moving toward the center of the foundation space before the concrete is poured. These spreaders are removed as the concrete is poured.
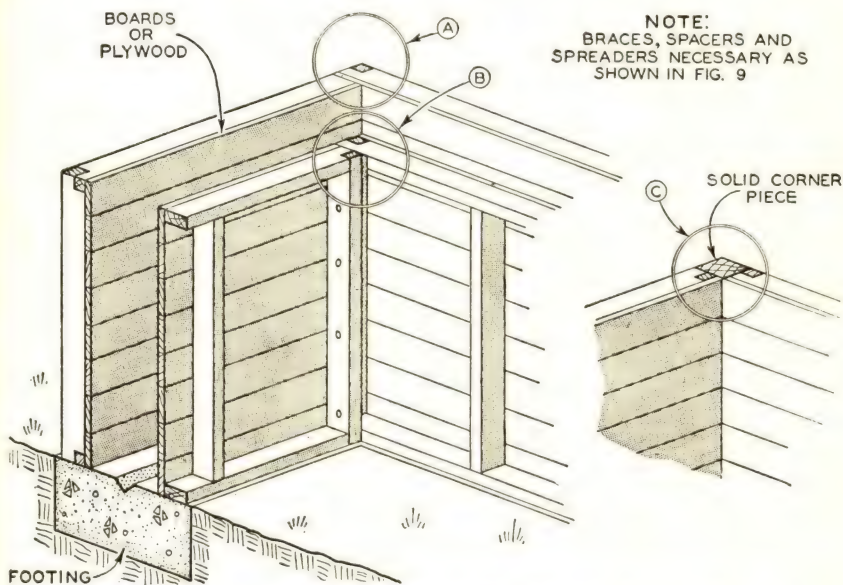
Fig. 10. Corner Construction Using Unit Forms Such as Shown in Fig. 9

Fig. 10 shows the method of corner construction for unit forms. There are many ways in which corners can be constructed but the ones shown at *A* and *B* are commonly employed. The construction shown at *C* utilizes a solid corner post. This is satisfactory but requires a solid post of an odd size.

In many instances where unit forms are being set up for a foundation, the units cannot be arranged exactly to complete the required formwork. For example, note the sketch in (C) of Fig. 11. The letters *JKLM* represent part of the outer formwork for a foundation and the letters *NOPQ* represent part of the inner formwork. Suppose that the foundation was to be 12″ thick. Further, suppose that exactly

four unit forms, each 4′ 0″ x 4′ 0″, made up the required length of the outer form. These forms are numbered *1, 2, 3,* and *4* in the sketch. If the corners are constructed as shown in Fig. 10, the distance between the inside edges of the outer formwork would be 15′ 4 inches. If the foundation is to be 12″ thick, the inner forms *OP* will have to be 13′ 4″
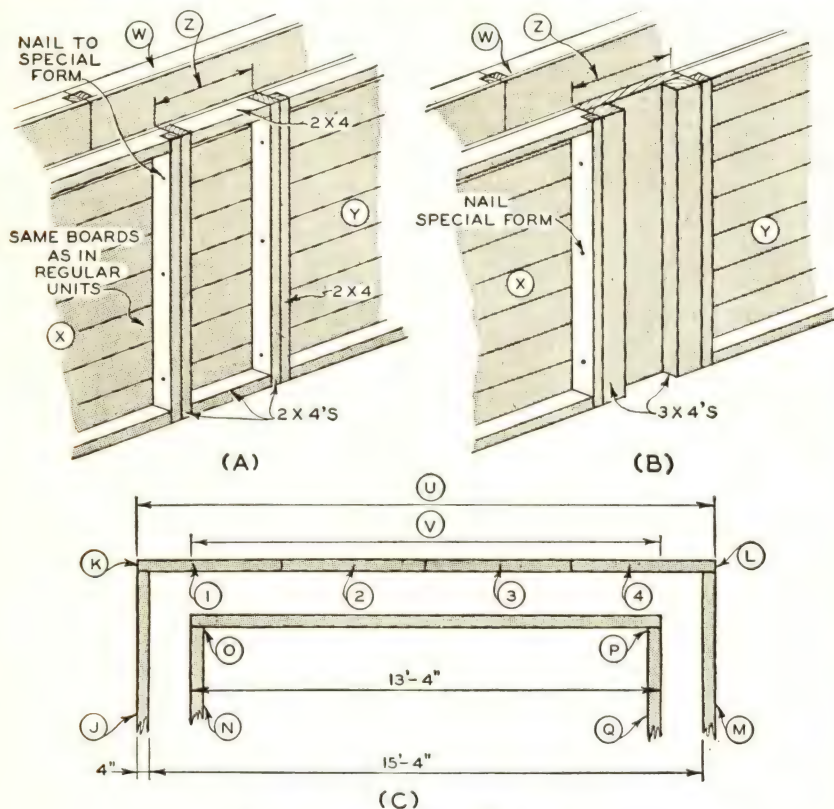
Fig. 11. Inserts for Use with Unit Forms

long. If only 4′ 0″ x 4′ 0″ unit forms are available, three of them can be used between *O* and *P*, leaving a gap of 1′ 4″ without a form. To overcome this difficulty, inserts such as shown in (B) of Fig. 11 are constructed.

In (A) of Fig. 11, *W* and *X* are the outer and inner formwork respectively. It can be assumed that the distance, *Z*, is 1′ 4 inches. The insert is made using 2 x 4's and short lengths of the same width

boards found in the regular size unit forms. It is constructed so that its boards are in line with the boards of the regular units on either side of it.
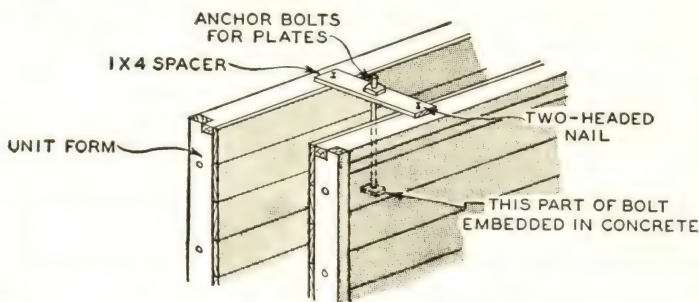
Fig. 12. Form for Holding Foundation Anchor Bolt in Place Prior to Pouring of Concrete

In (B) of Fig. 11 is shown a simpler type of insert. This type makes use of 2″ planks of various widths up to 10 inches. If distance Z were 10″ or less, this form could be used. Gaps in formwork greater than 10″ must be closed with inserts of the type shown at (A).

Many foundations have anchor bolts for wood sills embedded in the concrete at intervals. These bolts must be held in their proper positions prior to the pouring of the concrete and while the concrete hardens. Fig. 12 shows how spacers can be used for this purpose.
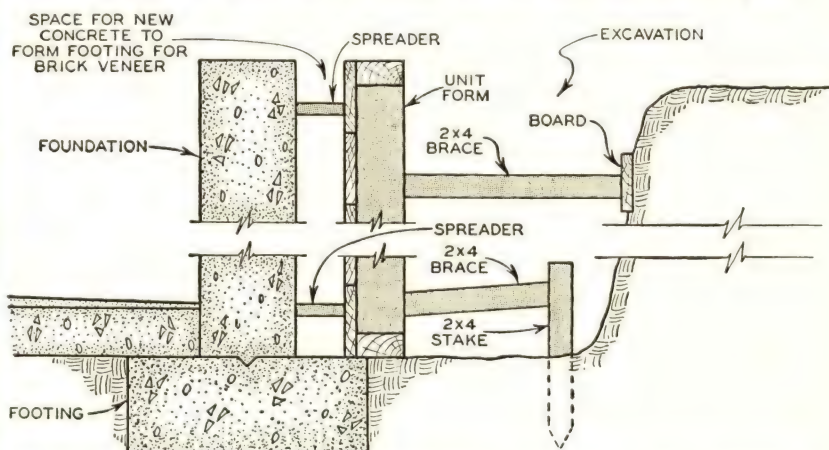
Fig. 13. Formwork for Adding New Concrete to Old Foundation to Make Provision for Addition of Brick Veneer

When frame residences are to be remodeled and a brick veneer surface added to the exterior walls, the foundations must be enlarged to provide the necessary support for the heavy veneer. Fig. 13 shows a typical method of using unit forms for that purpose. The forms are held in place by braces and stakes and by separators. The separators should be removed as the concrete is poured.

TAILOR-MADE FORMWORK. As mentioned previously, tailor-made formwork is constructed especially for specific jobs and is not re-used. It
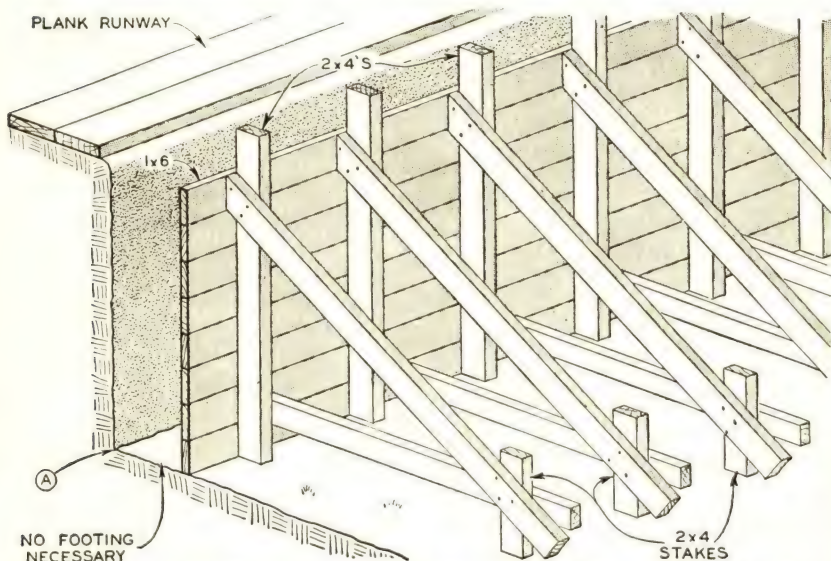
Fig. 14. Formwork for Foundation Where the Excavation Side Serves As the Outer Form

is constructed of studding and boards together with stakes, bracing, separators, wire, and spacers. There are several ways of constructing such formwork. These are described and illustrated in the following material.

Fig. 14 shows the formwork for a low foundation where the side of the excavation serves as the outer form. Note that the earthen wall is perpendicular and that the excavating has been done so as to create a square corner at *A*. The inner formwork is made especially for the job and is braced in much the same manner as was described for unit forms. A runway of 2 x 6, 2 x 8, or 2 x 10 planks is provided for wheelbarrows to prevent their caving in a portion of the side of the

excavation. There is always danger when the side of the excavation is used as the outside form, that portions of the excavation wall will crumble during the pouring of the concrete and thus weaken it.

Foundations and other concrete walls are often required at places other than where an excavation has been made expressly for them. In such cases, the forms must stand alone except for bracing. A condition of this kind is shown in Fig. 15. Here the outer and inner formwork is made by nailing boards to studding. The studding is
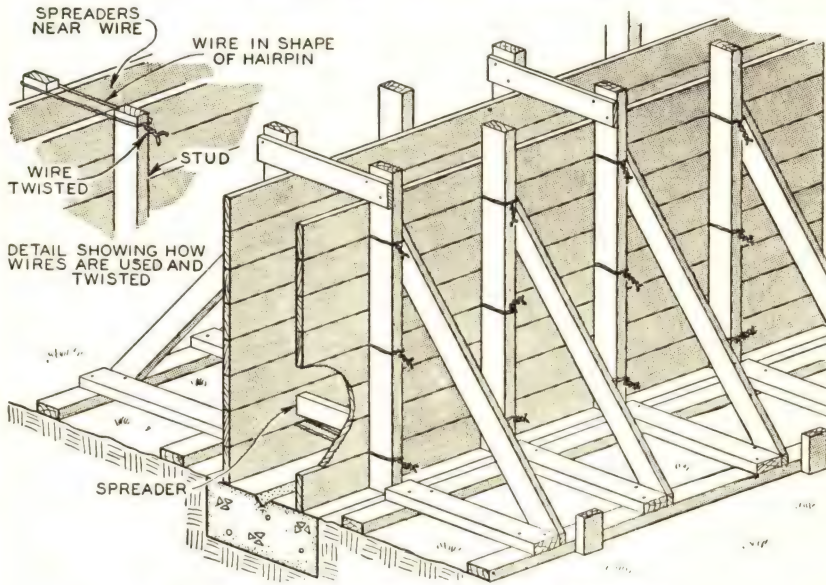
Fig. 15. Tailor-Made Forms for Concrete Foundation

braced in much the same manner as illustrated in Fig. 9. For formwork of this kind where the foundation or wall is over 4' 0" high, the braces should be attached to every other stud. Note that spreaders and spacers are required and that wire ties are necessary. The spreaders must be placed near the wire ties.

The corner construction for formwork such as illustrated in Fig. 15 is shown in (A) of Fig. 16. This is a top or plan view. The studs at *12, 13, 14, 15, 23,* and *24* make up the corner construction with the boards overlapping at *V* and *W* as shown

In a few instances where footings are not required beyond having
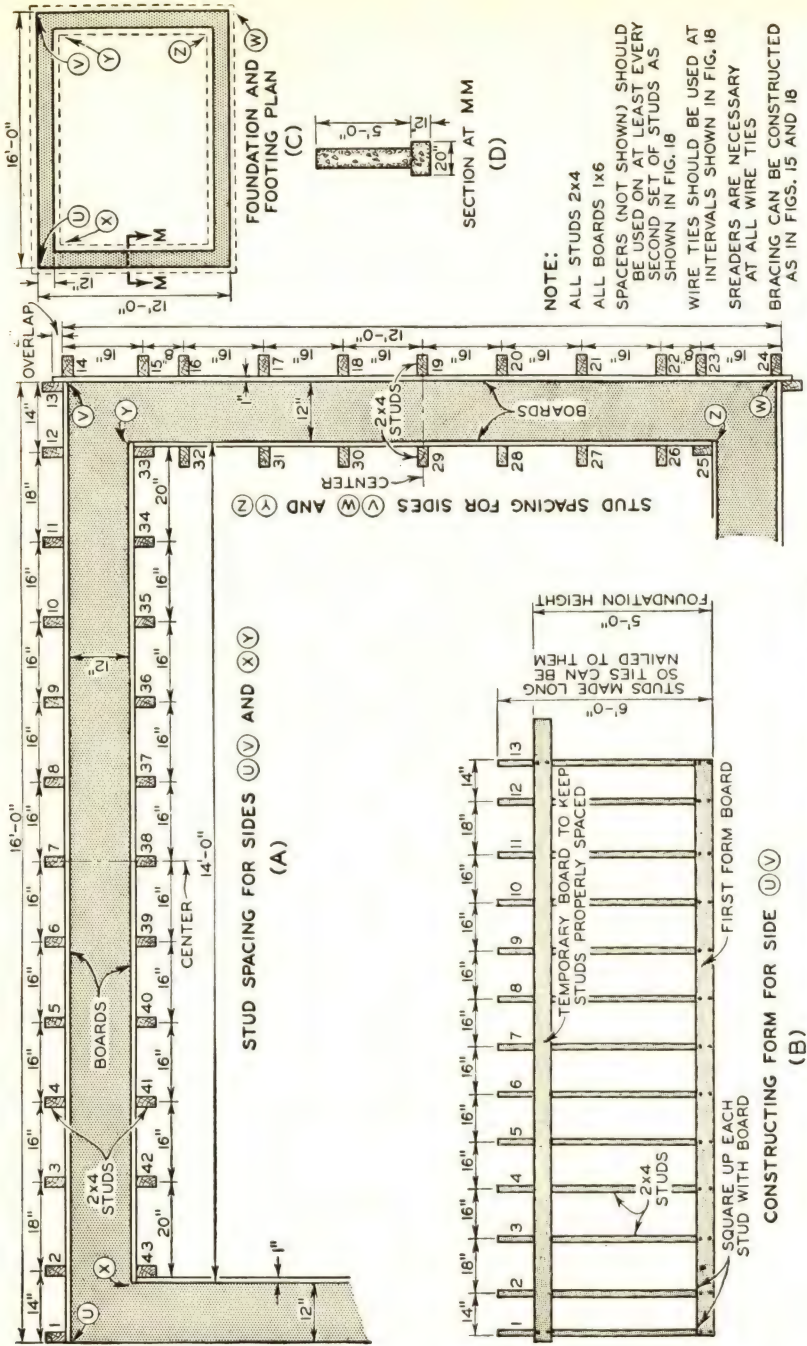
Fig. 16. Corner Construction and Other Details for Tailor-Made Formwork Shown in Figs. 15 and 18

concrete foundations or walls extend below frost line, it is possible to use the firm earth of the excavation wall for the below-grade part of the concrete and formwork for that part above grade. Such formwork is illustrated in Fig. 17. The concrete below grade is poured first and allowed to set. Once the concrete has hardened, the above-grade formwork is constructed. Note that the above-grade part of the foundation or wall is not as thick as the below-grade part and that the above-grade formwork rests on the below-grade concrete.
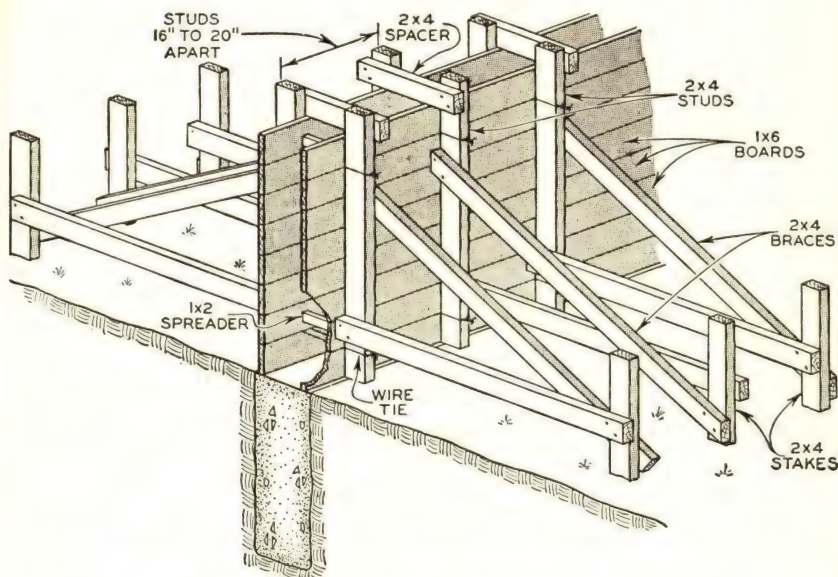
Fig. 17. Tailor-Made Formwork for Concrete Foundation or Wall

The formwork is constructed similarly to that shown in previous illustrations. The bracing and stakes are planned to keep both the top and bottom of the formwork securely in place. Spreaders are necessary as shown in previous illustrations. The spacers are nailed to extensions of the studs. Wire ties should be used near the bottoms of each pair of studs to make doubly sure that the formwork does not spread apart when the heavy concrete is poured into the forms. The height of these forms is only about 4′ 0″ which permits the studs to be placed farther apart. For higher forms, the studs should be closer together.

When concrete foundations are required, they usually are placed close to the side of the basement excavation. Fig. 18 illustrates one of the most common types of tailor-made formwork for such a situation. The inner form is held in place at the bottom by a runner and by stakes, one of which must be placed for each stud. The top of the formwork is held in place by braces which are in turn anchored by stakes. The outer formwork is held in place at the bottom in the same manner as the bottom of the inner formwork. The top is secured by
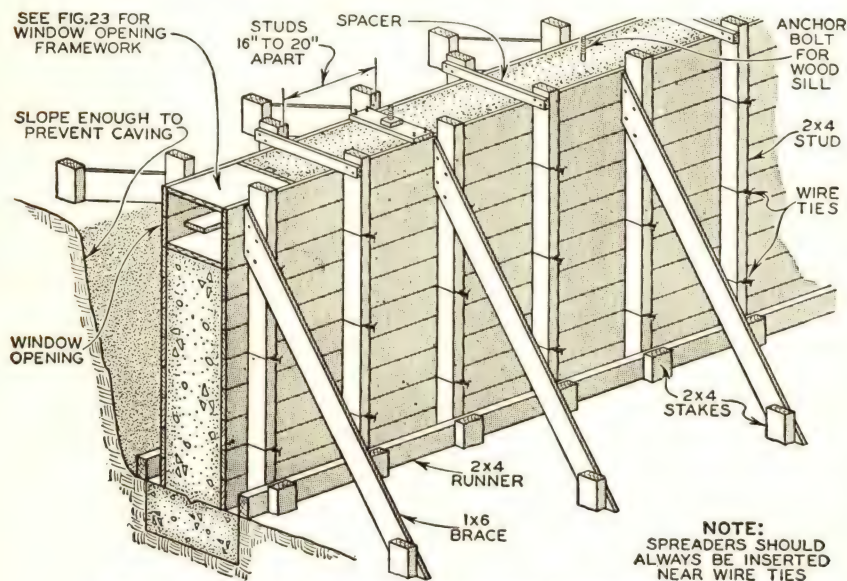
Fig. 18. Tailor-Made Formwork for Concrete Foundation or Wall

shorter braces and stakes. The braces and their stakes should not be placed at greater intervals than every other stud. Spacers, spreaders, and wire (as shown by detail in Fig. 15) are necessary.

Fig. 19 illustrates a cross section of tailor-made formwork for a foundation where a wheelbarrow runway is required in placing the concrete. This formwork is practically the same as that shown in Fig. 18 except for the 2 x 4 bottom plates and the manner of bracing. The runway is convenient for pouring concrete and is not too expensive or difficult to construct. The scaffold 2 x 4 verticals should be located at every second stud in the formwork and the cross bracing nailed to

every second vertical. The 1 x 4 formwork braces should be placed at every second stud. The scaffold verticals should be placed on boards which are held in place by stakes driven at frequent intervals. The planks for the runway should be supported by horizontal 2 x 4's spaced at the same intervals as the scaffold verticals and supported by the scaffold verticals and the 2 x 4 and 1 x 6 located at X and Y respectively. The X and Y pieces should run the full length of the formwork. Other bracing and details are evident in Fig. 19.
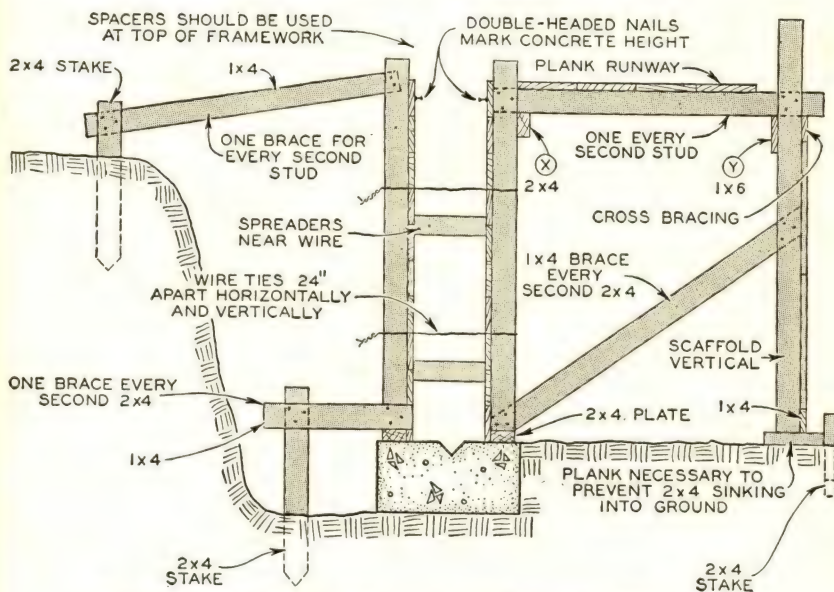
Fig. 19. Section of Typical Formwork with Runway for Wheelbarrows

Many buildings not requiring basements, such as garages, some farm structures, etc., still need foundations. Sometimes even footings are required with such foundations because of the soil conditions. Fig. 20 shows the formwork for such a foundation. If footings are necessary, the excavation must be made accordingly. The formwork is constructed similarly to that illustrated in Fig. 2.

The formwork for the foundation is similar to other formwork previously described except for the wales and the manner of bracing. Note that the spreader, which is a requirement of good construction, is placed near the wire tie.

SPECIAL FORMWORK.   There are many instances in concrete work which require what can be called special formwork and which is often a combination of unit and tailor-made forms.

Formwork for Beam Bearing Surfaces.   In most residences and other buildings which have basements, beams of one kind or another must be supported at one end of their length by the foundation.
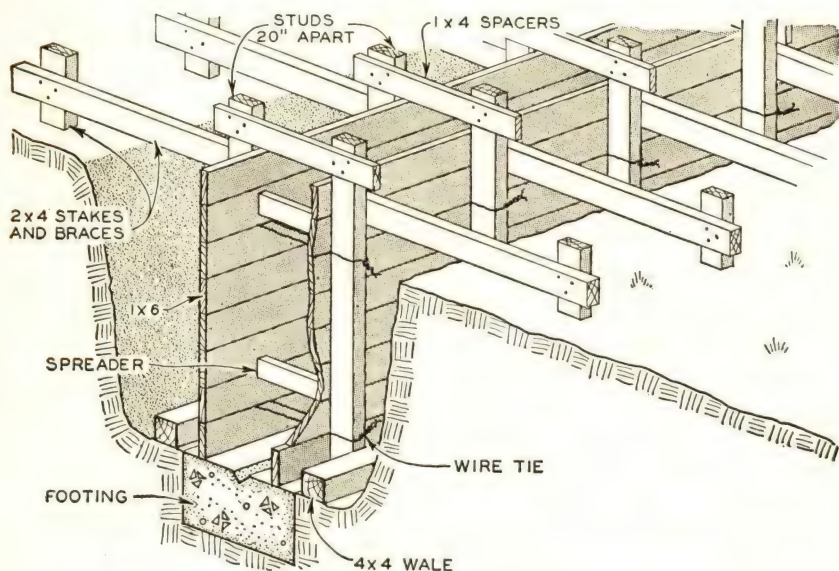
Fig. 20.   Tailor-Made Formwork for Concrete Foundations **Where** No Basement Is Required

Generally, about 4″ of bearing surface is required. Fig. 21 shows the formwork at the top of a concrete foundation which provides a pocket at least 4″ deep in which a beam end will have sufficient bearing. Such pocket formwork can be cut into any tailor-made form and held in position as illustrated by the figure.

Formwork for Columns.   The formwork for simple concrete columns used in residences and other small buildings as a means of supporting simple beams, are constructed as shown in Fig. 22. The four sides of the formwork can be put together separately and then assembled and held together by the use of 2 x 6 planks and 1 x 6 boards. The lower 2 x 6 planks are made long enough to be nailed to stakes

A 2x4 OR 1x4 NAILED IN POSITION OF DOTTED LINE WILL KEEP POCKET FROM SAGGING

1x8 FORM BOARDS

4x4
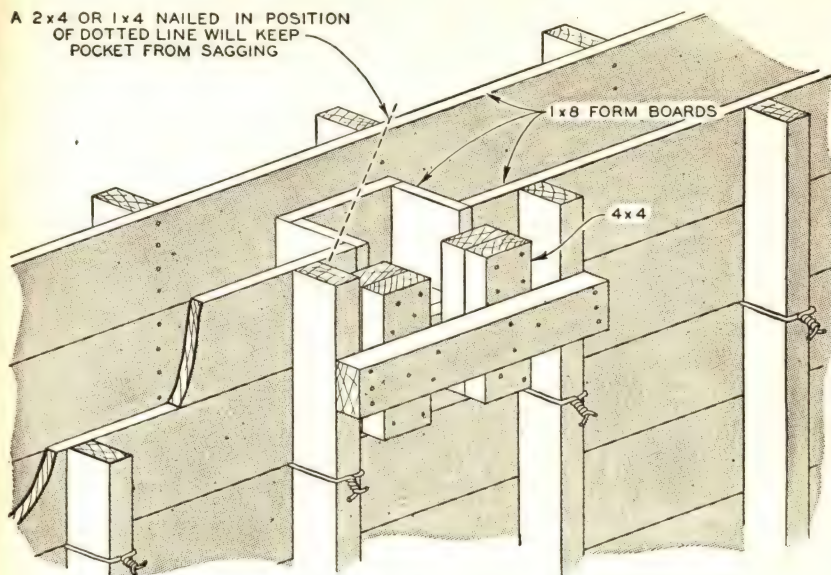
Fig. 21. Pocket Form for Making Beam Support at Top of Concrete Foundation

1x6

X

NOTE:
COLUMNS OVER 6 FEET
SHOULD BE BRACED
FROM (A) TO (B)

CORNER
SIDE
SIDE
"V" STRIP

DETAIL OF (X)

1x4

A

2x6

1x6

2x4
STAKES

TWO-HEADED NAILS

B
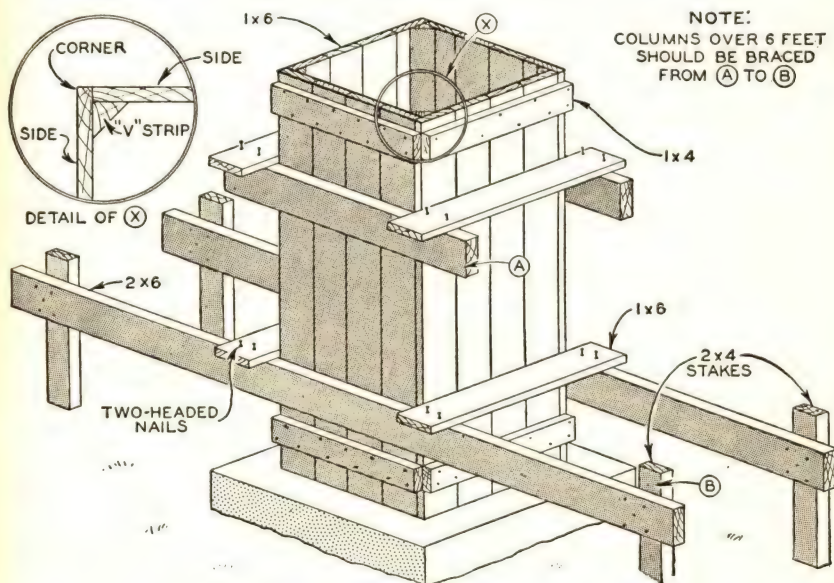
Fig. 22. Typical Forms for a Column

for support and to keep the formwork in the correct position. If the column formwork is more than 4′0″, braces made of 1 x 6 boards should be nailed to the stakes at points near the top of the formwork to prevent it from tipping or getting out of vertical plumb. Note that **V** strips can be used at all four corners to bevel the edges of the column.
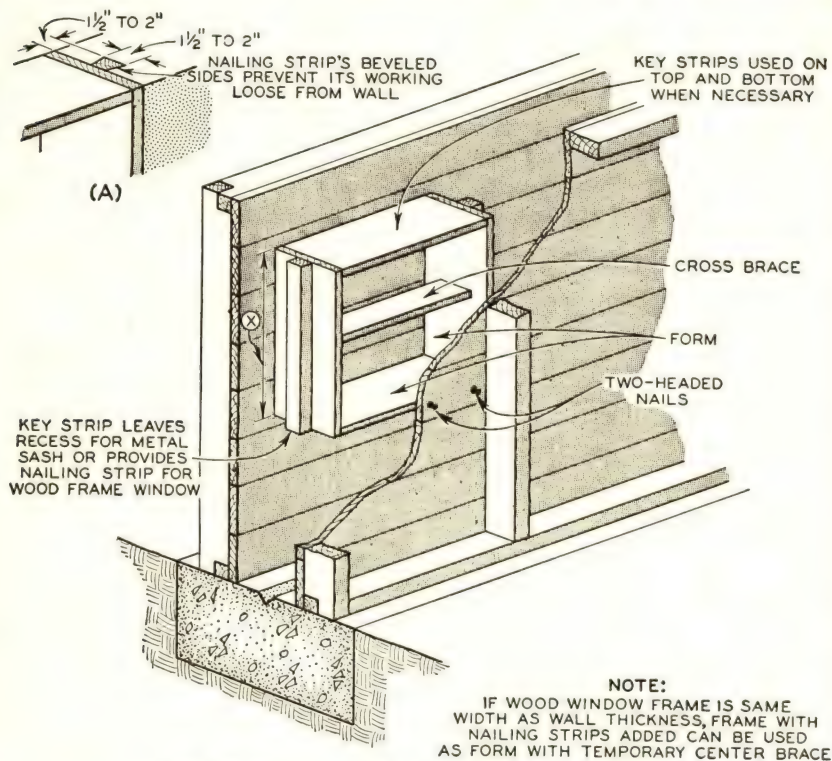
Fig. 23. Form for Window in a Concrete Foundation

Formwork for Window Openings. Forms for window openings frequently must be provided for in concrete walls or foundations. If wood frame windows are to be used, the window frame itself can be employed as the formwork as shown in Fig. 23. Key strips, which remain in the concrete, are nailed to the frame on two sides or all four sides as a means of holding the frame in place and preventing a crack between the frame and the concrete through which wind and rain could enter. If the wall or foundation is thicker than the frame is deep, filler

pieces (shown for door frames in Fig. 24) can be used temporarily and removed when the concrete has set. If metal sash windows are to be used, a wood form must be made similar to the metal window frame and removed when the concrete has set. Key strips are necessary according to the needs of the particular make of metal sash being used. These keys are nailed to the formwork and also removed when the concrete has set.

For small window openings not more than 18″ square, one cross brace as shown in Fig. 23 is sufficient. For larger openings, one horizontal brace should be used for each foot of height and one vertical brace for each foot of width of the opening.
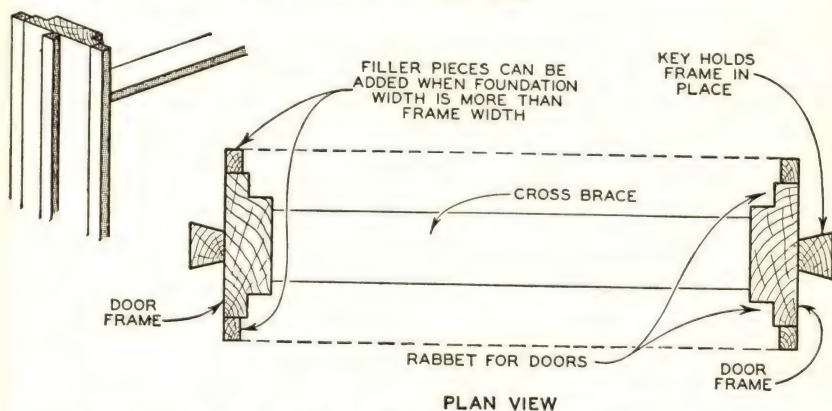
Fig. 24. Form for Door in a Concrete Foundation

Note in sketch (A) of Fig. 23 that the keys for wood window frames can be beveled.

For wood frame windows, height X as shown in Fig. 23, is the height of the window. For metal sash windows, this height should be sufficient to include a stone sill 4″ high, generally used in conjunction with the sash.

If only part of a window is within a concrete wall or foundation, the formwork is used in exactly the same manner as previously described except that part of it extends above the point (see nails indicating the height of the foundation in Fig. 19) where the top of the concrete occurs.

Either type of window formwork can be held securely in position by two-headed nails driven through the formwork boards into the
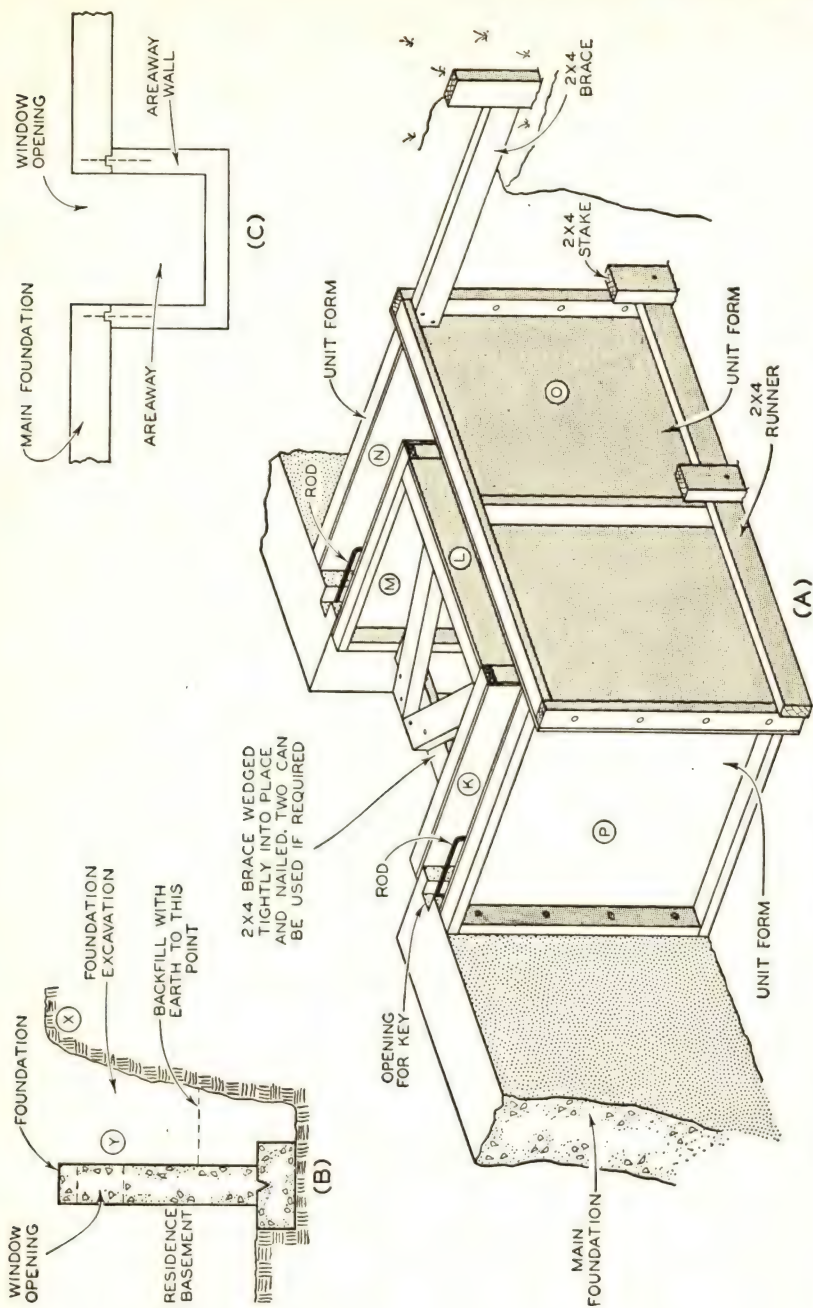
Fig. 25. Unit Forms Used for Shallow Areaway Walls

window formwork. The use of such formwork is also illustrated in Fig. 19.

Formwork for Door Openings. When door openings are required in concrete walls or foundations, formwork such as shown in Fig. 24 can be used. Keys are employed for the same purpose as explained for the formwork for window openings. If the wall or foundation is thicker than the depth of the frame, filler pieces can be added and then removed when the concrete has set.

For ordinary door heights, horizontal cross braces should be used at intervals of about 2′ 0″. At least one vertical brace is necessary to prevent the heavy weight of the concrete from bending the head part of the door frame.

The foregoing explanations for window opening formwork generally apply to door opening formwork with the exception that few metal doors are ever used.

Formwork for Areaways. The tops of foundations are frequently at the same height as the grade illustrated by the sketch in (B) of Fig. 25. Windows in such foundations are therefore below grade and must have an areaway in order that light can enter them from the exterior. A typical areaway is shown in (C) of Fig. 25.

From the sketch at (B), it can be seen that the excavation extends a foot or two beyond the foundation. This is necessary to allow sufficient room in which to construct the foundation formwork. This additional working area must be considered when planning the areaway formwork wall.

In some cases the main foundations are poured before the areaway walls. When this is done, keys and reinforcing rods, shown in (A) of Fig. 25, are necessary. The keys prevent the areaway walls from moving sideward and the rods prevent it from moving downward or out.

Typical areaway formwork is illustrated in (A) of Fig. 25. Note that unit forms and inserts (see Fig. 11) can be used. The size of the units and inserts depends on the dimensions and thickness of the areaway walls. Braces of 2 x 4 are required to strengthen the interior formwork, *KLM*, as shown. Generally, two sets of such braces are used, one near the top and one near the bottom of the formwork. The outer formwork, *PON*, can be braced in any of the ways previously illustrated.

Before the formwork for such areaway walls can be constructed, the space between the foundation wall and the side of the excavation must be backfilled as shown in (B) of Fig. 25, to a depth determined by the bottom of the areaway floor. The extent of this backfilling is indicated by the dash line. The backfilling earth should be
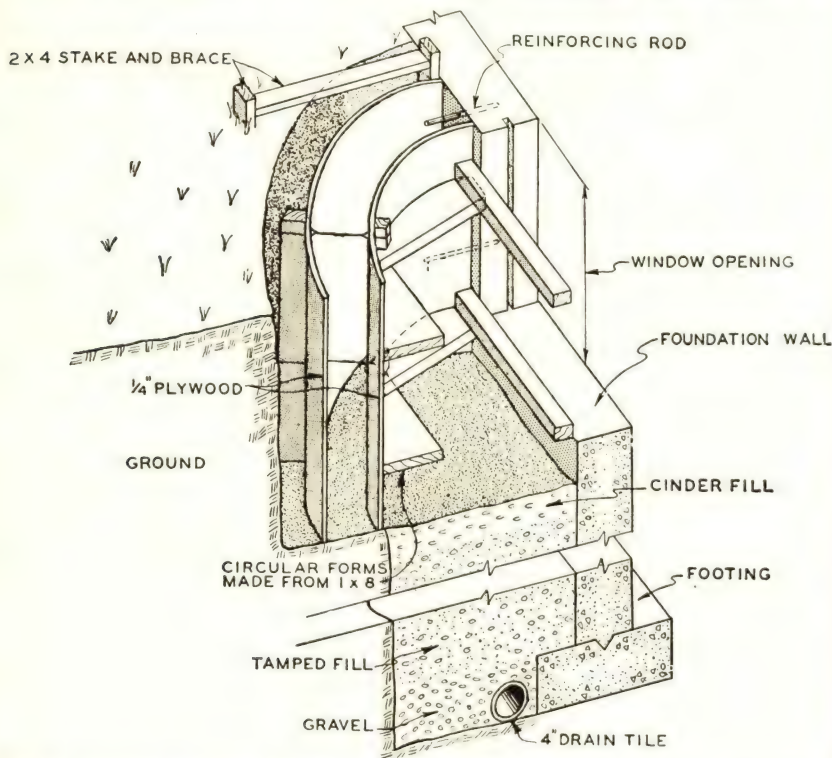
Fig. 26. Rounded Forms for Half-Round Areaway around Window at Top of Foundation

wetted down and carefully tamped to make sure that it is firm and will not settle after the areaway walls have been poured. Some further excavation may have to be done at X in order to allow sufficient room in which to construct the formwork.

The best way to make areaway walls is to pour them at the same time the main foundation is poured. They are then an integral part of the foundation. Forming the areaway walls in this manner makes absolutely certain they will not sag or crack away from the founda-

tion. The formwork in such a case must be constructed by an experienced carpenter.

Fig. 26 shows how the formwork for a circular areaway wall is constructed. It should be noted that this areaway is being constructed after the foundation walls have been poured.

Formwork for Front Entrance Porches. The forms for the foundation-like footings under concrete front entrance porches are made in the same manner described for the rectangular areaway in Fig. 25.

Machine Foundation Formwork. When heavy machines of one kind or another are to be set in place, a concrete foundation is usually necessary. Fig. 27 illustrates how the formwork can be constructed for such a foundation, 24″ long, 20″ wide, and 10″ deep. The boards for this formwork should be at least 2″ thick. They can be nailed or screwed together at the corners. The use of triangular or **V** strips at the corners of the

Fig. 27. Formwork for Concrete Base for Heavy Machinery

formwork gives the finished foundation beveled edges. The bolts used to fasten the machine to the foundation are held in the proper position by 2 x 4's until the concrete sets.

Reinforced Beams and Floors Formwork. The formwork for reinforced concrete beams and floors and for combinations of these with columns requires intricate formwork which should be constructed only by experienced carpenters.

Miscellaneous Formwork. Many miscellaneous and useful objects can be made of concrete with the use of not too intricate formwork. The fence end post and brace illustrated in Fig. 28 is a good example. The section view at (A) shows the post and right angle brace. The post and brace should extend at least 3′ 6″ into the ground (or below frost line) as is also indicated in (A). The post is 12″ square and is 5′ 0″ above the earth or grade line. The brace is about 4″ or 5″ thick and 4′ 0″ long. It slopes from a point about 16″ above grade down to the grade. Other details can be obtained from a study of views (A) and (C). Note that in (A) there are two braces shown. The second
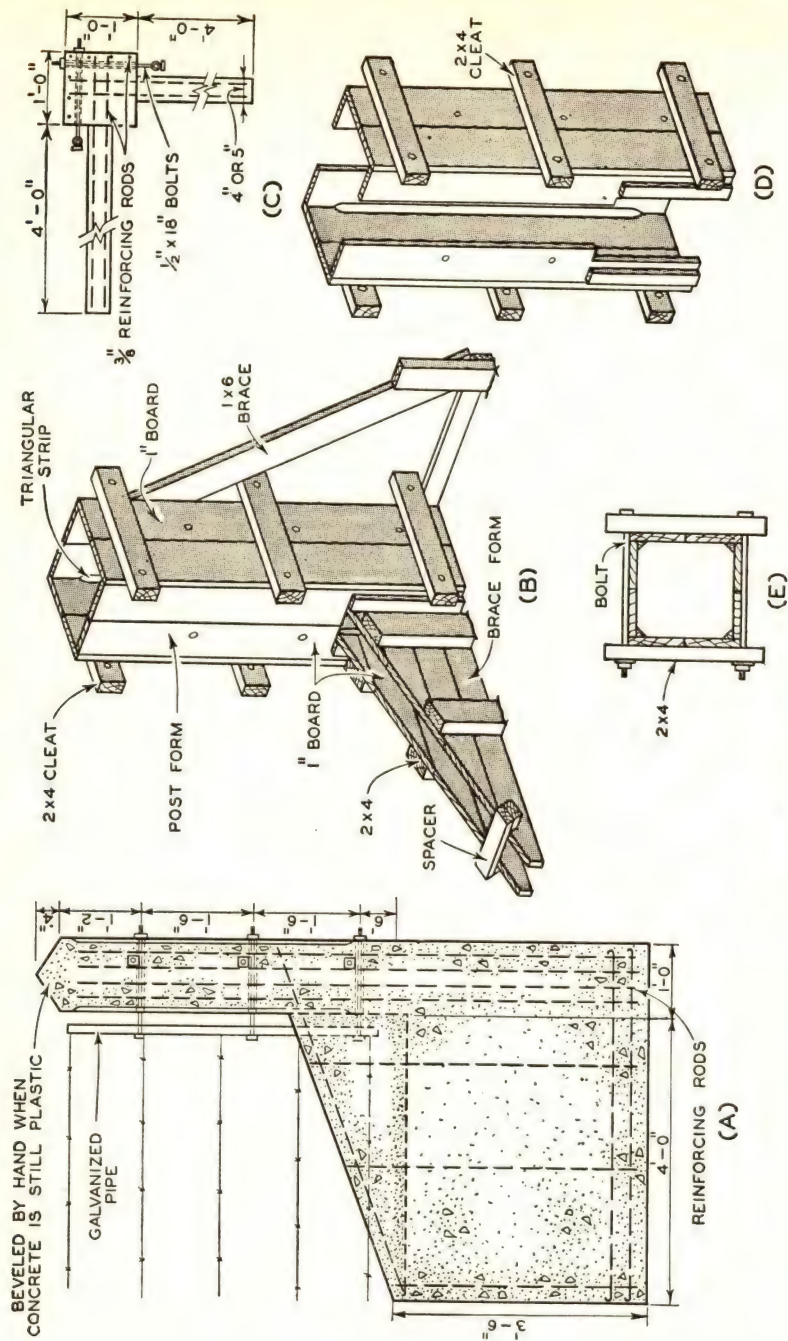
Fig. 28. Forms for Fence End Post and Braces

(C) 4'-0" · 1'-0" · 1'-0" · 4'-0"
⅜" REINFORCING RODS
½" x 18 BOLTS
4 OR 5

(D) 2x4 CLEAT

(B)
TRIANGULAR STRIP
1" BOARD
1 x 6 BRACE
BRACE FORM
POST FORM
1" BOARD
2 x 4 CLEAT
SPACER
2 x 4

(E) BOLT · 2x4

(A)
BEVELED BY HAND WHEN CONCRETE IS STILL PLASTIC
GALVANIZED PIPE
REINFORCING RODS
4"·1'-2"·1'-6"·1'-6"·6"
1'-0"
4'-0"
3'-6"

brace is exactly like the first and enables the post to be used in a corner.

The formwork for this end post with brace is shown in (B), (D), and (E) of Fig. 28. The form boards are 1" thick and 2 x 4's are used for the cleats. Note that triangular strips are used to produce the beveled edges. They also could be used to bevel the top edges of the brace. Bolts are recommended as the means for holding the formwork together. It is usually more convenient to construct the formwork in two parts as shown at (D). This facilitates their removal and re-use.

The fence wire is fastened to galvanized iron pipes as shown at (A) and (C). These pipes are held in place by ½" bolts, which extend through the concrete. Holes for these bolts are made by passing greased rods through the formwork. These rods are removed before the concrete has a chance to harden.

If the earth is fairly firm, no forms are needed below the grade line. The necessary excavation is carefully made, the formwork is set in place, and the concrete poured. The formwork is held in position by braces and stakes in the same manner as previously illustrated for other formwork. For example, the stake and bracing shown in (B) illustrates how the formwork can be held erect and in position above the excavation. Additional bracing should be used as required.

The dash lines and heavy dots shown in (A) and (C) indicate steel reinforcing rods which are used to give the concrete added strength. These rods are absolutely necessary and must be put in at the locations and spacings indicated. The position and spacing of the rods can be visualized better if it is remembered that the heavy dots are top views of the rods while the dash lines are the side views. For posts and braces of this kind, ¼" and ⅜" round steel rods are generally satisfactory.

The number, size, and spacing of reinforcing rods in any concrete requiring such added strength is a matter which should never be guessed at or approximated. Unless such reinforcing is properly designed and placed in the formwork, it is practically useless and the resulting concrete would be unsafe or would fail entirely. This fact is stressed because of its great importance. A structural engineer or an architect should always be consulted unless, as in Fig. 28, the amount,

size, and spacing of rods has been given. The United States Government, through the Department of Commerce, the Portland Cement Association, and other such organizations, distribute many manuals which include a great many typical concrete objects along with the prescribed reinforcing. These manuals can be obtained free or for a small fee.

DESIGN OF FORMWORK

Before the design and use of formwork is undertaken, there are several items of general importance to consider which apply to both unit and tailor-made formwork.

Formwork Lumber. Wood for formwork must be of a kind that is easily worked and retains its shape when exposed to wet concrete and general weather conditions. White pine is usually considered the best formwork wood because of its strength and the ease with which it can be worked. However, it has two drawbacks in that its softness prevents much re-use and it is the most expensive of all suitable formwork wood. Hemlock, spruce, fir, and yellow pine are satisfactory woods for formwork due to the fact that they are not difficult to work, can be re-used as formwork or for other purposes, and are not too expensive.

There is some difference of opinion among authorities pertaining to the use of green or well-seasoned woods for formwork. Probably the best compromise between extreme opinions is to use wood which is neither green nor well-seasoned. Green wood is apt to shrink and cause cracks through which the concrete paste might escape while fully-seasoned wood is apt to swell when in contact with the wet concrete, causing bulges in the formwork. But for small concrete jobs such as footings, foundations, sidewalks, etc., neither shrinkage nor swelling is apt to occur to any appreciable extent, especially in unit forms which are used time after time.

Lumber having knots or decayed sections should not be used for formwork since such defects cause leakage of cement paste and unsightly concrete surfaces when the forms are removed.

SYNTHETIC AND PLYWOOD LUMBER. Certain boards made of cellulose fibers are now available. These boards are hard and smooth and may be obtained in larger pieces than regular wood. The use of

such boards, especially when impregnated with oil, makes smooth concrete surfaces. They may be re-used many times. However, this material requires very careful bracing in order to avoid bulging when concrete is poured into the forms.

Plywood is frequently used because it can be obtained in large sheets which facilitates smooth concrete surfaces and ease in form erection. Only plywoods which have been impregnated with oil or other waterproofing can be re-used, especially in unit forms. Ordinary plywood can be used once if the surface which will be next to the concrete is sprayed with some oily or waterproofing agent just prior to the time the concrete is poured.

For better joints, the use of tongue-and-grooved or ship-lapped regular lumber boards is recommended. All regular lumber should be well planed, preferably on all four sides. This is especially recommended for the sides of the boards which come in contact with the concrete. Rough-sawn board surfaces are apt to stick to the concrete, causing difficulties in removal, and give the concrete rough and unsightly surfaces.

Size of Lumber. For footing formwork, as illustrated in Figs. 2, 4, 5, 6, and 7, it is best to use either 2 x 6, 2 x 8, or 2 x 10 planks because they have more stiffness than 1″ material. The stakes should be of 2 x 4's while spacers can be 2 x 4, 1 x 4, 1 x 6, 1 x 2, or whatever other size lumber is available.

For unit forms such as shown in Figs. 8, 9, 10, 11, 12, and 13, the boards should be 1″ but not less than 7/8″ in thickness and 6″ wide. The 6″ width works out to better advantage because the forms are constructed in over-all sizes which are multiples of two. The framing members should be 2 x 4's. Stakes and braces should be of 2 x 4's, although 1 x 4 or 1 x 6 braces sometimes can be used. The spacers can be made of 2 x 4 or 1 x 4 lumber, whichever is handy. Spreaders are made of 2 x 2 or 2 x 4 lumber. Sometimes 4 x 4 corner posts are used with unit forms but not often.

For tailor-made formwork such as shown in Figs. 14, 15, 16, 17, 18, 19, and 20, the boards should be at least 7/8″ thick and 6″ wide. The studs should be 2 x 4's. All stakes should be 2 x 4's. The braces can be either 1 x 4, 1 x 6, or 2 x 4 lumber as indicated in the previously mentioned illustrations. When spacers are nailed to studs, they can be

as small as 1 x 4. Runners, as shown in Figs. 15 and 18, should never be less than 2 x 4's. When wales are used, they should be at least 4 x 4's. When plates, as in Fig. 19, are required, they should never be less than 2 x 4's. Spreaders should be of the size previously mentioned. Scaffolds should have vertical supports no smaller than 2 x 4's, runway supports no smaller than 2 x 4's, and braces no smaller than 1 x 4's.

For miscellaneous formwork such as shown in Figs. 21, 22, 27, and 28, ⅞" or 1" boards should also be used. Cleats should be of 2 x 4 or 2 x 6 material, depending upon the size of the formwork. For example, an end fence post which is not very high nor large in cross section is safe with 2 x 4 cleats, while a column which may be 5' 0" to 8' 0" high and 12" or more in section should require 2 x 6 cleats. As usual, stakes should be 2 x 4's and braces may be either 1 x 4 or 1 x 6 lumber.

Boards not less than 2" in thickness should be used for machinery foundations.

Synthetic and plywood boards may be ¼" thick for small formwork such as illustrated in Fig. 26, but for foundations and other heavier walls it should be at least ¾" thick.

Forms for window and door openings must be made of material 2" thick or more. The vertical and horizontal braces usually are 2 x 4's.

Prior to being built into formwork, all braces, stakes, runners, wales, verticals, etc., should be inspected to make sure they are sound and not cracked or decayed. Failure of any such member might cause a whole form to bulge or fail, which would result in serious material loss and possible injury to workmen.

Design of Unit Formwork.   Units of 4' 0" x 4' 0" size should have 2 x 4 frames which have been carefully joined and nailed at the corners. The type of joints shown in Fig. 8 are recommended, although plain butt joints may be used if strap iron in the form of an angle is used to reinforce the corners. At least one 2 x 4 stiffener should be used, running at right angles to the boards. The boards should either be nailed or screwed to the 2 x 4 stiffener and framework.

As indicated in Fig. 8, holes should be drilled through the vertical frames in order that the various forms composing a wall or foundation formwork can be securely bolted together. Bolts for holding units

together are recommended over nails because the units can be re-used many times without splitting or otherwise ruining the frames.

A 2′ 0″ x 2′ 0″ unit does not require a stiffener. Units over 4′ 0″ long should have stiffeners placed at not more than 2′ 0″ intervals. If long units are more than 4′ 0″ high, the stiffeners should be spaced about 12″ apart.

It is preferable for the boards in the forms to run horizontally because the board impressions in the concrete will then be horizontal and in the position boards, siding, etc., are usually seen. If necessary, the edges of the boards are planed in order to insure a tight joint between them. The ends of the boards must be sawed perfectly square so that the forms will fit perfectly without leaving a large crack. So that spreaders will hold the forms exactly the right distance apart, they also must be sawed square.

Design of Tailor-made Formwork. For most tailor-made formwork, the studs can be spaced 16″ to 20″ on centers. For low walls such as illustrated in Fig. 20, the studs need not be closer than 20″, but for higher forms, as indicated in Figs. 18 and 19, the 16″ spacing is recommended. The studs should extend above the boards in order that they can be tied with spacers. The spacers are used on every other set of studs as shown in Fig. 18, or on every set as indicated in Fig. 20. The studs should be planned so that it is possible to tie them with spacers at right angles to the wall or foundation.

Both tops and bottoms of the formwork must be securely held in position by braces, wales, runners, or plates. It does not matter which of the many types of bracing illustrated is employed so long as the formwork is held securely in the proper position. Care should be taken to construct ample bracing because the formwork must be held rigidly in its correct position. Failure of braces could mean loss of material and injury to workmen.

Spreaders should be placed at the intervals shown by the wire ties in Fig. 18. One spreader should be used near each wire tie. These spreaders are removed as the poured concrete reaches their level in the forms. For this reason they should be lightly toenailed at one end only.

Two-headed nails should be used in nailing all bracing into place. These nails facilitate form removal and save damage to the lumber,
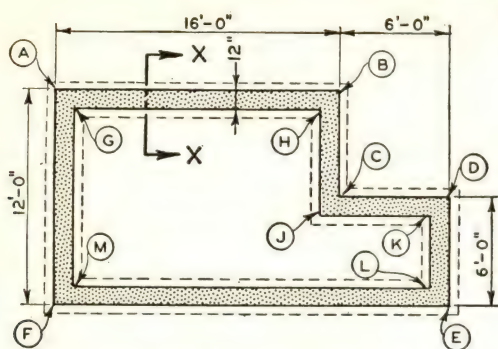
FOOTING AND FOUNDATION PLAN
(A)

SECTION AT X-X
(B)

(C)
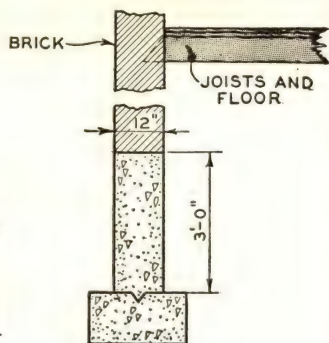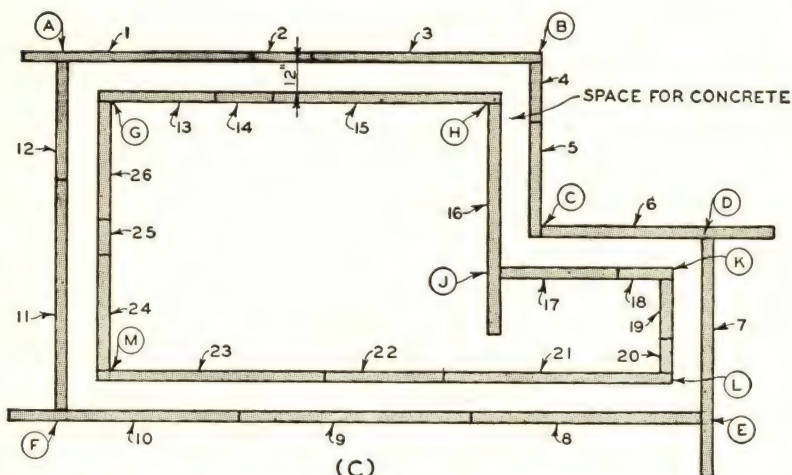
UNIT SCHEDULE

8 FOOT LENGTHS
   UNITS 1-3-6-7-8-9-10-11-15-16-21-23

4 FOOT LENGTHS
   UNITS 5-12-13-17-22-24-26

2 FOOT LENGTHS
   UNITS 2-4-14-18-19

INSERTS
   UNIT 20 IS 1'-8" LONG
   UNIT 25 IS 1'-4" LONG

NOTE Y: IN THIS
ILLUSTRATION IT IS
ASSUMED THAT MASON
HAS THREE SIZES OF UNITS
2, 4, AND 8 FEET LONG
AND ALL 4 FEET HIGH

Fig. 29. Planning the Use of Unit Forms

leaving it serviceable for other purposes. Such nails are also used for fastening window and door opening forms into place, allowing the inner and outer formwork to be removed without damage to the widow or door frame used as formwork.

A careful study of the tailor-made forms illustrated in this chapter will reveal much about their design.

It is possible to buy several kinds of metal combination spreaders and spacers. These, when used, take the place of wooden spreaders, spacers, and wire ties. The metal type is so constructed that most of it remains in the concrete, the ends being made so they can be twisted off when the forms are removed.

CONSTRUCTION OF FORMWORK

Two examples of formwork construction are treated in the following explanations. The procedures set forth are typical and are so described as to be especially useful to masons of limited experience.

The sketch in (A) of Fig. 29 shows the footings and foundations plan for a small building. It can be assumed that the footings are already in and that the foundation for which forms must be provided is 12″ thick. The foundation, as indicated in the sketch at (B), is 3′ 0″ high. For the purpose of this example, it is further assumed that the mason has three sizes of unit forms available as indicated by note Y in Fig. 29.

Inexperienced masons can easily plan the formwork by first drawing a large-scale plan view of the foundation. A scale of at least ¾″ = 1′ 0″ is recommended. Such a plan is shown in (C) of Fig. 29 by the outlines ABCDEF and GHJKLM. By drawing the rectangles representing unit forms (top view of the form standing as it would in formwork) to the same scale, their positions in the whole formwork can be planned.

First, consider the outer side of the foundation AB shown in (A) and (C) of Fig. 29. This side is 16′ 0″ long. It can readily be seen that four of the 4′ 0″ long units would exactly form that side. Wherever they can be employed, however, the use of 8′ 0″ long units is best because they can be put into place more quickly and because fewer units used in any length of wall require less bracing. Therefore, two 8′ 0″ long units and one unit 2′ 0″ long can be used. The 2′ 0″ unit provides

the necessary overhang for constructing the formwork corners. These are shown in the plan at (C) and are numbered *1, 2,* and *3.* It does not matter that one end of unit *1* extends beyond the corner at *A*.

Side *BC* is 6′0″ long. Two units numbered *4* and *5* are used and are 2′0″ and 4′0″ long respectively.

Side *CD* is also 6′0″ long. Here, one 8′0″ unit numbered *6* is used. Side *DE* is treated in the same manner. Side *EF* is composed of three 8′0″ units numbered *8, 9,* and *10.* There is an overhang here as there was at *A, D,* and *E,* but this is unimportant. The last side, *FA,* is 12′0″ long, so one 8′0″ unit, *11,* and one 4′0″ unit, *12,* are used.

The interior side, *GH,* is only 14′0″ long because it stands inside two 12″ sections of foundation. Units *13, 14* and *15,* being 4′0″, 2′0″, and 8′0″ respectively, are used as shown. Side *HJ* is 6′0″ so the 8′0″ unit, *16,* can be used with one end extending beyond the corner at *J.*

This process is continued for the balance of the inner formwork. However, two inserts, *20* and *25,* are necessary because no combination of the available units exactly make the required lengths for sides *KL* and *MG.*

It should be stressed that there are many other combinations of unit forms available and possible. The combination shown in (C) of Fig. 29 is typical. The unit schedule shown below the sketch in (C) illustrates the manner of counting the total number of each unit size necessary for the job. When the unit forms are delivered to the job, they are distributed around the excavation so as to be handy.

When preparing to set up the unit forms, the best practice is to draw blue chalk lines on the footing which represent the exact width and position of the foundation on the footing. The unit forms are then set up on these lines.

Suppose the interior formwork is set up first. Bolt units *13, 14,* and *15* together as shown in Fig. 9. Next, bolt units *24, 25,* and *26* together and put unit *16* in its approximate position. Use two-headed nails to fasten units *26* and *13* together at corner *G* and units *15* and *16* together at corner *H*. Assemble all other inner units in the same manner. They will stand up by themselves at this point. Next, drive stakes such as *X* and *Y* in Fig. 9. Lay the two runners *M* and *N* and the flat 2 x 4 braces. Push these flat braces up against the bottoms of the units until the board sides of the units are exactly on the inner chalk line.

Then nail them to the runners using two-headed nails. Fasten the nailing blocks also shown in Fig. 9, and put the diagonal braces loosely in place. Before each diagonal brace is nailed to the flat brace, the units should be tested with the plumb rule. When they are perfectly vertical, the diagonal brace is nailed to the flat brace.

For a foundation only 3′ 0″ high, spreaders placed one above the other and at about 4′ 0″ intervals, as shown in Fig. 9, are sufficient. Toenail the spreaders to the inner form faces.

Assemble the other formwork in the same manner, bolting and nailing all units together. If there is not room between the units and the edge of the excavation for bracing, such as shown in Fig. 9, then bracing such as shown in Fig. 13 or as illustrated between the forms and embankment in Fig. 19, may be used. Whatever type of bracing is used, the braces should not be more than 4′ 0″ apart and preferably placed at all joints between units.

When all braces are in place, the corners should be checked to see that they are square. The units should be checked to make certain that they are truly vertical. The formwork should be inspected to be sure that all joints are tight. Any needed corrections should be made before concrete is poured.

Prior to pouring concrete, the interior of both inner and outer forms must be marked at several places to indicate where the top of the concrete should be. This process is necessary in order that the top of the foundation all the way around will be at exactly the same level. Unless special care is taken to accomplish this, all structural parts above the foundation will require further costly work.

One simple but effective method of establishing a uniform foundation height is illustrated in Fig. 30. However, the help of a second person is necessary.

The first step is to mark the desired foundation height on the inside of the formwork, preferably at a corner. In this example, the foundation height is 3′ 0″ above the footing and is represented in (A) of Fig. 30 by the letters *FH* on the surveyor's rod.

Note the leveling instrument in Fig. 30. This instrument stands on three legs and consists of a telescope which can be adjusted so as to be perfectly level but which is free to be rotated in the horizontal plane. If, as in (B) of Fig. 30, one looks through the leveled telescope
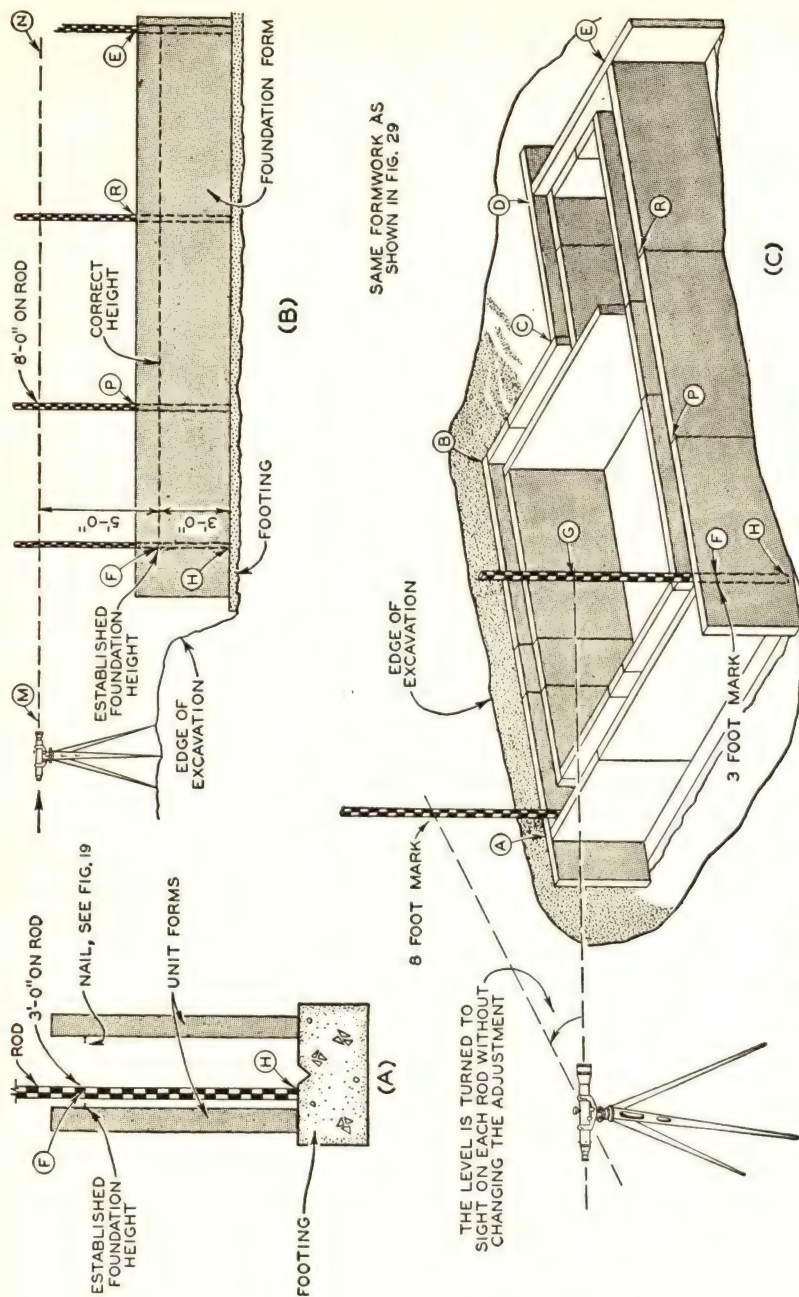
Fig. 30. Use of Level Instrument to Establish Uniform Foundation Height

in the direction of the arrow, the line of sight MN will be perfectly horizontal. Suppose a surveyor's rod is put between the forms as shown in (A). The established foundation height is at 3′ 0″ on the rod. Next, suppose the leveling instrument and rod are positioned as in sketch (B), with the rod being held at F. The foundation shown is the same as illustrated at FE in sketch (C).

Looking toward the rod through the leveling instrument with the rod held in a vertical position, the cross hair visible in the telescope falls on (it can be assumed) the 8′ 0″ mark on the rod. This point is 5′ 0″ above the 3′ 0″ mark on the rod. If the rod is placed at position P in sketch (B) with its bottom resting on the footing, the foundation height will be exactly 5′ 0″ below the reading on the rod seen through the leveling instrument. This height is marked on the formwork. Due to irregularities in the height of the footing, the telescope rod reading may be greater or less than the 8′ 0″ found in the first reading at F. However, a distance 5′ 0″ down from any reading will give the foundation height desired. Read-ings are made all the way around the foundation as shown by the letters F, P, R, E, D, C, B, and A. Unless the foundation height is thus marked at several points along the formwork, it can easily become incorrect when the concrete is poured.

Two-headed nails can be used to mark the level of the foundation before the concrete is poured as shown in Fig. 19. Another method is to nail triangular strips of wood along the interior of the formwork as the correct height is found. These strips, shown in Fig. 31, serve as a guide when the concrete is being poured in addition to beveling the edges of the foundation.

Fig. 31. Use of Triangular Strips to Mark Foundation Height and to Give the Top Edge of Foundation a Bevel

If a leveling instrument is not avail-able, the long plumb rule or level can be used to establish the correct foundation height around the forms. However, this method is not nearly as accu-rate as when a leveling instrument can be used.

The foundation height is first established as shown in Fig. 32. One end of a triangular strip is nailed to the inside of the form at the established height. The strip is then held against the formwork and its level checked with the plumb rule. When level, it is lightly nailed at its other end. This process is repeated, nailing one end of another length of triangular strip level with the first piece. Special care must be taken to get each strip as nearly level as possible all around the forms.
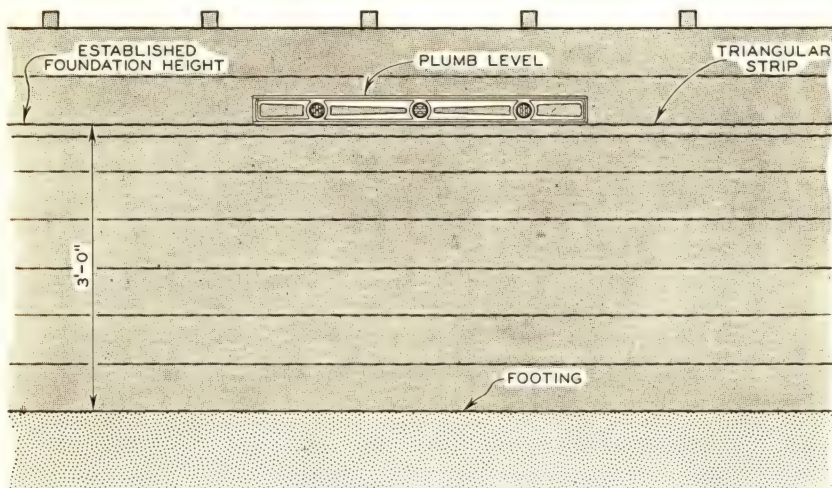
Fig. 32. Method of Establishing Uniform Foundation Height Using Plumb Level

No matter how much care is taken, the last strip to be nailed in place is not likely to coincide with the level of the first strip when the two meet. This is the disadvantage of this method. Unless the level of the last strip coincides with the level of the first strip, the levels of all strips must be checked again and again until all strips are at about the same level.

The extreme difficulty in getting all the strips level is because it is not possible to get the bubble in the plumb rule exactly in the middle of the glass each time a strip is checked. However, on such small work as the foundation in this case, the plumb rule method is usually accurate enough.

The sketch in (C) of Fig. 16 illustrates the footing and foundation plan of a small building. It can be assumed that the footings are

already in and that the forms for a 12″ foundation are to be erected. The foundation, as indicated in sketch (D), is 5′ 0″ high. Tailor-made formwork is required.

As was explained in the previous example, inexperienced masons should make a large scale drawing of the foundation similar to the one shown at (A) in Fig. 16. Lines indicating the boards can be drawn in next.

The stud locations for the outer formwork, UV and VW, and the inner formwork, XY and YZ, should be planned first. Find the centers of each formwork length and draw lines indicating them as noted in sketch (A). Assuming the studs will be 16″ center to center, lay out 16″ divisions along the sides in both directions from the centers of the formwork, using the same scale as for the foundation plan view. Next, draw in lightly, the plan view of the studs at the 16″ divisions.

Along the inner formwork, XY, there are four 16″ divisions on either side of the center. A fifth division of the same dimension would not quite reach the two corners. Therefore, it is permissible to move studs *43* and *33* into the corners, making their distances from studs *42* and *34* slightly more than 16 inches. The studs in the outer formwork must be opposite the studs in the inner formwork. Studs also must be located at both ends. Therefore, studs *2* and *12* are drawn more than 16″ from studs *3* and *11* so as to be opposite studs *43* and *33* in the inner formwork. Studs *1* and *13* are drawn at the ends of the formwork as required. Studs *2* through *12* in the outer formwork are now exactly opposite studs *43* through *33* of the inner formwork as required in order that spacers can extend across the space between the outer and inner formwork from one stud to another.

Planning stud locations for the inner and outer formwork, VW and YZ, is done in exactly the same manner. The studs in the formwork for the balance of the foundation are also planned in the same manner. The numbering of studs as illustrated at (A) is recommended as a means of estimating the quantity needed.

The inner and outer formwork for each side of small building foundations can be assembled flat on the ground and then raised into the correct position. For the outer formwork of side UV, the studs are laid on the ground in approximate positions as shown in (B) of Fig. 16. The bottom or first form board should be nailed to stud *1* after

being squared to it by the use of a carpenter's square. Stud *2* should then be spaced exactly 14" on center from stud *1*. The stud should be squared to the first form board and nailed just as was stud *1*. A temporary board should be squared and nailed to the studs near their top ends as a means of maintaining proper spacing throughout their lengths. The balance of the studs can now be placed and the first as well as the temporary board squared and nailed to them. All of the form boards are now nailed to the studs and the temporary board removed. This same procedure is followed in assembling the formwork for the other outer and inner sides.

The holes for the wire ties should be drilled in all outer formwork and the wires inserted before the formwork is raised into position on the footings. The holes for the wire also should be drilled in all inner formwork before it is raised and set in place.

The outer formwork is raised one side at a time and temporarily braced in the correct position. The corners are nailed together with two-headed nails in such locations as to allow them to be withdrawn without injury to the concrete or formwork when the formwork is removed. The board side of the formwork should touch the chalk line as explained for the description of the use of unit forms. The stakes are driven and bracing erected as in Figs. 17, 18, or 19.

Next, put the bottom of the inner formwork on the footings and raise the formwork about 4/5 of the way so that the top of the inner formwork is about 2' 6" from the top of the outer formwork. Brace it in this position temporarily. With the outer and inner formwork that far apart, a man can walk between them and toenail all necessary spreaders to the outer form. He can also shove the wires attached to the outer formwork through the holes provided in the inner formwork. Now the inner formwork can be raised to the correct position tightly against the spreaders. The corners are nailed and all stakes and bracing such as shown in Figs. 17, 18, or 19 driven and assembled. The wire ties are then twisted tight as shown in the sketch in Fig. 15.

All formwork should be checked to make sure it is plumb in all directions, that all spreaders are in the correct position, that all wire ties are tight, and that the formwork is tight enough to avoid the loss of any cement paste. Finally, the spreaders can be nailed to their proper positions.

Any necessary window or door opening formwork should be lowered into position and nailed securely by the use of two-headed nails driven from the outside of the formwork. Beam pockets or other special formwork should also be put in place. The formwork is then ready for concrete.

TREATMENT OF FORMWORK

All authorities agree that the interior surfaces of formwork—those surfaces which come in direct contact with concrete—should be treated in any one of several ways as a means of obtaining a finished concrete of better appearance, as a means of preserving the lumber of the formwork for other uses, and as a means of simplifying formwork removal.

Wetting Formwork. This treatment consists of spraying or mopping the interior surfaces of the formwork with plain water just before the concrete is poured. The theory behind this treatment is that if the dry formwork is wetted just before the concrete is poured, the wood will not absorb water from the concrete. If the formwork should absorb water from the concrete, improper setting takes place, leaving the concrete unsatisfactory in appearance. Wetting the formwork also prevents the concrete from sticking to it. This facilitates removal, prevents rough concrete surfaces, and helps preserve the formwork for use as lumber or for re-use as formwork.

Oiling Formwork. Instead of water and to better accomplish the same results, a light, clear lubricating oil is sometimes sprayed or brushed on the formwork surfaces just prior to the time the concrete is poured. If the oil is too thick for easy application, it should be cut with about an equal amount of kerosene.

This oil treatment should not be used if the concrete surfaces are to be painted or have stucco or plaster applied to them. In such cases, paraffin oil diluted with benzine is recommended.

If steel reinforcing rods are to be used in concrete, special care must be taken not to apply oil of any kind to the rods. Oil on the rods would tend to destroy the all-important bond between them and the concrete, thus defeating their purpose.

FORMWORK REMOVAL

The period of time after which formwork may be removed has been specified for all concrete structural members elsewhere. It should

be remembered that in warm weather concrete tends to set or harden much more rapidly than in cold weather. If formwork is removed before concrete is well set, edges and surfaces may be damaged. Experience is the best guide as to the time of form removal but if there is any doubt, ample time should always be allowed.

The formwork should be removed carefully so as to preserve the good appearance of the concrete surfaces, to avoid nicking the concrete, and to preserve the lumber in the formwork.

When wire ties are used, they must be cut at both outer and inner forms before the formwork can be removed. Then, after the forms have been stripped, the wire ends are clipped close to the concrete and punched back unless the surface is to be stuccoed or plastered. If a pit hole is caused by punching back the wire, it should be pointed up with mortar which should then be rubbed to make it blend with the rest of the surface.

As the formwork is removed, it should be carefully cleaned of all particles of concrete. The tailor-made variety can be used as lumber for other parts of the building. Unit forms, after careful cleaning, should be stored out of the weather until they are needed again. This is the only way to make them last for repeated use and to maintain their surfaces in good condition. It is a good idea to inspect unit forms after each period of use and to repair them as is necessary. Careful handling also will help to preserve them.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. What the purpose is of spreaders in concrete formwork?
Answer. To maintain the correct width between the inner and outer parts of the formwork.

2. What the necessary condition of the soil should be in the bottoms of footing excavations?
Answer. The soil must be firm and undisturbed.

3. How the various sections of unit forms should be held together when they are used as foundation formwork?
Answer. By at least three nuts and bolts through the side framing members.

4. Why it is that no oil should be put on steel reinforcing bars at the time the formwork surfaces are being oiled?

Answer. Because the oil would tend to destroy the all-important bond between the concrete and the steel, which in turn would defeat the purpose of the reinforcing.

5. What the purpose is of formwork?

Answer. To hold concrete in the desired shape until it hardens and gains strength.

6. Why formwork must be left in place longer before being removed in cold weather than in warm?

Answer. Because in cold weather, concrete sets and gains strength more slowly than in warm weather.

7. What spacing is allowed for the studs in tailor-made formwork?

Answer. For low walls or foundations, for example, the studs may be spaced as much as 20″ on centers. For walls or foundations over 4′ 0″ high, the studs should not be spaced more than 16″ on centers.

8. Why it is usually dangerous to use the side of the excavation as formwork for foundations?

Answer. Because some of the soil is apt to fall into the concrete. If this occurs, the concrete may be weakened or become porous.

9. How formwork cost compares with the cost of materials on any job?

Answer. In many cases the formwork costs more than the materials.

10. How foundations are secured to footings?

Answer. Grooves are formed in the center of the top surface of the footings. These are filled by the foundation concrete when it is poured. This keeps the foundation secure.

11. How areaway walls are secured to the foundation when they are not poured as an integral part of the foundation?

Answer. By keys, formed in the foundation, and by reinforcing rods which are embedded in both the foundation and the areaway walls.

12. How wire ties are removed from the finished concrete once the formwork has been stripped.

Answer. They are not removed. Instead, they are cut off at the surface of the concrete and punched back into the concrete unless the surface of the concrete is to be plastered or stuccoed. When they are punched back into the concrete, the resulting hole is pointed up with mortar and then rubbed to make it resemble the concrete.

13. What pockets are and what their use is in foundation formwork?

Answer. They are recesses in foundations to provide spaces for beam-end bearing surfaces.

14. Why it is that white pine is not used much for formwork?

Answer. Because it is too expensive and because its softness makes it easily nicked and otherwise injured.

15. Why it is that green lumber should not be used in formwork?

Answer. Because it is likely to twist, warp, and shrink when exposed to wet concrete and the sun.

16. What sized boards are best for use in constructing formwork?
Answer. Boards either ⅛" or 1" in thickness and 6" wide.

17. Why spreaders must be sawed perfectly square at their ends?
Answer. So they will hold the formwork exactly the right distance apart.

REVIEW QUESTIONS

1. Explain why the formwork used in conjunction with concrete must be strong.

2. Why are cracks in formwork objectionable?

3. What is the purpose of spacers?

4. Explain the purpose of wire ties and describe how they are installed in tailor-made formwork?

5. What is the purpose of the groove in the top surface of a footing? How is it formed?

6. Under what circumstances are footings poured in two parts?

7. What is a wale?

8. Where are runners used?

9. What are unit form inserts?

10. How is the formwork for a window opening in a foundation constructed?

11. If concrete surfaces are to be stuccoed, can oil be used on the formwork?

12. When bolts are required in concrete such as in corner fence posts, how are the holes for them provided for in the concrete?

13. What kind of boards are best for formwork?

14. Why should the interior surfaces of formwork be smooth?

15. What advantages are gained when the interior surfaces of formwork are wetted just prior to the time the concrete is poured?

16. Why is it serious when cement paste escapes through cracks in the formwork?

17. Why is the use of two-headed nails an advantage in the construction and erection of formwork.

CHAPTER II

Design and Construction of Footings

QUESTIONS CHAPTER II WILL ANSWER FOR YOU

1. *How much weight can soft clay, dry sand, coarse sand, gravel, hard shale, and solid rock be expected to support?*
2. *What determines the shape of foundation footings and why is this shape so important?*
3. *When is the use of reinforcing rods desirable and what are some of the precautions to be observed?*
4. *What loads must a concrete foundation footing support and how are they determined?*
5. *What are the chief precautions to be observed when building footings?*

INTRODUCTION TO CHAPTER II

The importance of the tank as a military weapon has been demonstrated so many times since its development in 1916 that any discussion of the part it has played in shaping history is unnecessary. The track-laying principle, in which an endless belt fitted with broad "feet" transmits the weight of the vehicle to a large area of ground, is the invention which made the tank a possibility. Without the endless tread, the tank could never have been evolved.

The camel has always been associated with the desert. The ability to go without water for three days at a time has made it invaluable to desert travelers. But more important is the peculiar structure of the camel's foot. Large to begin with, it spreads as weight is placed upon it. In effect, nature has equipped the camel with permanent "snowshoes" which enable it to walk easily on the soft, yielding sand where most other animals would bog down hopelessly.

At first thought there would seem to be very little in common among tanks, camels, and the study of masonry. As a matter of fact, in one respect at least, the parallel is quite close. The great weight of the tank would immediately force its narrow wheels deep into the ground the moment a tread was lost, leaving it immobile. The camel would not be fit as a desert beast of burden if its feet were not particularly adapted to its sandy habitat. Similarly, any building, unless constructed on bedrock, probably would settle immediately unless some means were provided to distribute the building's weight over a greater area. There are several ways in which this may be done but by far the most common is the use of footings.

Footings are simply widened sections of the foundation base designed to increase the area of the bearing surface of the bottom of the foundation. The size of the footing is determined, first, by the resistive qualities or firmness of

the soil and, second, by the weight which must be supported. The softer the soil, the larger the footing must be. Again, the heavier the weight the foundation must support, the larger the foundation must be.

Footings are found also under columns, chimneys, pilasters, under porches and stairs, and under wall projections. In brief, a footing is used whenever the soil condition is such that it is incapable of supporting the load or where excessively heavy loads are encountered.

Although the construction of footings is one of the easiest tasks confronting the mason on any particular job, the necessity for them is so great that a thorough knowledge of their design and construction is of prime importance. A study of the following pages will dramatize the need and importance of footings. The result of inadequate or poorly constructed footings is illustrated with descriptions of the reasons for the failures. The various types of footings are presented and their particular use pointed out. The design of footings is discussed. Finally, the actual building of typical footings is described, rounding out a most essential and informative chapter.

IMPORTANCE OF FOOTINGS

Footings comprise the first actual structural work to be done in the building of residences, stores, barns, and other structures. They are of great importance to the strength, appearance, usefulness, and safety of any building in which their use is required. Without good footings, a structure may easily develop unsightly cracks, off-level floors, and untrue doors and windows. If footings are properly designed, the excavations for them properly made, and they are constructed correctly, the structures they support are safe from the annoyances and dangers just noted.

Inexperienced masons and designers seldom realize fully the real importance of footings or appreciate the caution which must be exercised in their design and building. Footings are of major importance and they should be built with great exactness and care. This chapter explains the theory of footings, describes the various kinds and their proper use, tells how to design them, and, finally, shows how to build them.

THEORY OF FOOTINGS

In order to present the theory of footings, a typical example will be explained using a common type of foundation. This foundation is shown in cross section in Fig. 1. Note that the foundation has no footing and that it is 12″ thick and 8′ 0″ in height. The load on the foundation from the building it supports can be assumed to be 2,250 pounds per lineal foot.

Importance of Soil Condition. While the foundation supports the weight of the structure above it, the foundation in turn must be supported by the soil on which it stands. Concrete weighs 150 pounds per cubic foot, so a lineal foot of this particular foundation will weigh 150 × 8, or 1,200 pounds. This weight added to that which the foundation must support makes a total of 3,450 pounds per lineal foot which the soil must support. If the soil is not strong enough to support this load, the foundation will gradually settle, causing cracks and other annoyances in the structure above. It is possible for a foundation to sink far enough to cause the structure to collapse. For this reason, the strength or firmness of the soil must be considered when a building is being planned and provisions made so as not to overload it per square foot.
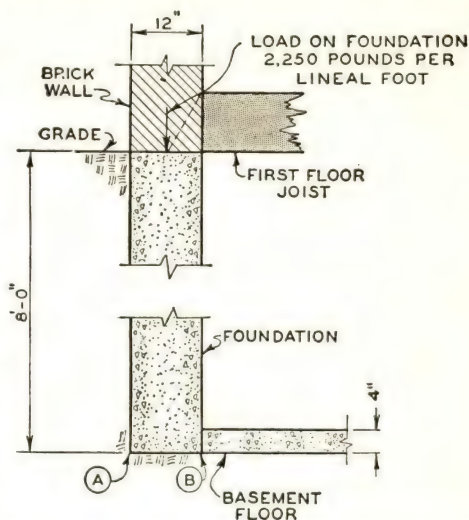
Fig. 1. Cross Section of Foundation without Footing

Soils vary greatly in their ability to support heavy loads. Table I gives the safe loadings for six common types. From this table it can be seen that soft clay, which is encountered most frequently, can safely support only one ton or 2,000 pounds per square foot.

TABLE I. SAFE LOADS FOR VARIOUS SOILS

TYPE OF SOIL	SAFE LOAD IN TONS PER SQUARE FOOT
Soft clay	1
Dry, fine sand	2
Compact coarse sand	3
Coarse gravel	4
Hard pan or hard shale	10
Solid rock	No limit

The foundation shown in Fig. 1 transmits a load of 3,450 pounds to the soil per square foot. If the soil is assumed to be soft clay, it obviously cannot support the foundation. Unless some other provisions

are made, the foundation will sink dangerously. However, if the bottom of the foundation is widened sufficiently, the load per square foot will be decreased to the extent that the soft clay will be able to support the load safely.

Distribution of Foundation Load.
Fig. 2 shows one method of distributing the foundation load over a greater soil area. This structural part is known as a footing and is shown at *ECFD*. To find the area per lineal foot which is necessary to support the foundation load without sinking, divide the load (3,450) by the safe load per square foot of the soil (2,000). Thus, 3,450 ÷ 2,000 = 1.725 square feet. Since this is approximately two square feet, it can be assumed that the load of the foundation will be distributed over this area. Therefore, the load from the foundation, when distributed over two square feet of surface,

Fig. 2. Cross Section of Foundation with Footing

amounts to 1,725 pounds per square foot. This is less than the maximum strength or firmness of the soil and the foundation will not settle or sink.

As indicated in Table I, some soils are safely able to support more than 3,450 pounds per square foot. In such cases footings are not actually required. However, most builders use them even under such circumstances as a safety factor against the slightest settling.

How far below grade footings are built depends on basement heights, if any, and on the frost level. All footings must be below the frost line in cold climates to avoid heaving and sinking as the soil freezes and thaws. Ordinarily, frost rarely goes deeper than 6' 0" in northern parts of the United States.

Footing Side and Bottom Shapes. One of the most important items concerning footings has to do with the shapes of their sides and bottoms. Unless these shapes are carefully considered in the design and building of footings, their usefulness and safety are greatly diminished.

SLOPING GROUND. Sometimes a residence or other structure must be built on sloping ground in such a way that the bottoms of the footings cannot all be at the same level. In such cases the footings should be "stepped" as shown in Fig. 3. The difference in level is made up by a series of horizontal surfaces, each as long as the degree of slope will permit. Steps such as *DC* and *BA* must be perfectly horizontal. Risers
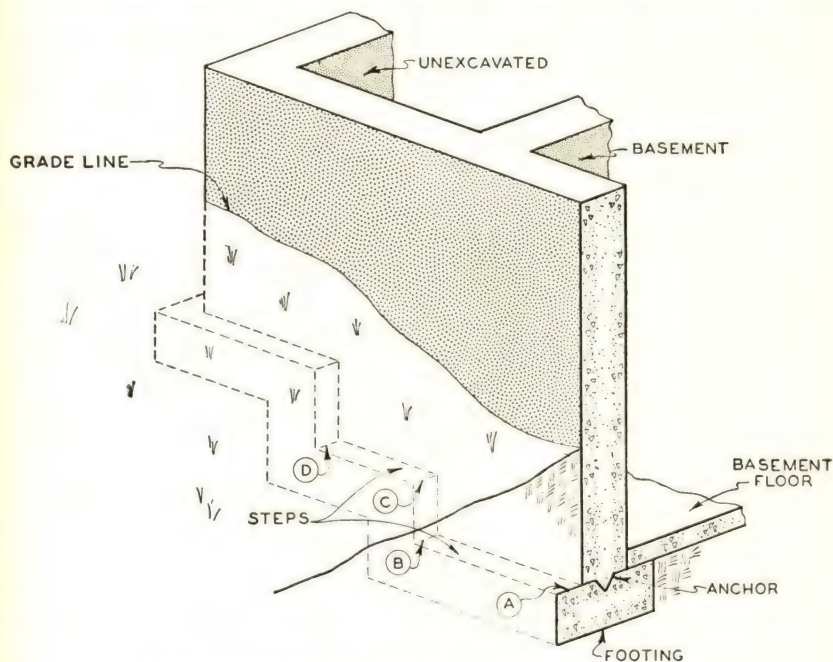
Fig. 3. Method of Stepping Wall Footings in Sloping Ground

such as *CB* must be perfectly vertical. This means that careful excavation work is important. If the steps sloped from *B* to *A*, for example, or if the risers leaned from the vertical, the footings might slip (move) or break under heavy loads. This would cause damage to the structure.

Fig. 4 illustrates another condition sometimes encountered where footings are built at right angles to the slope of the ground. In a case of this kind, the bottom of the excavation must be perfectly level or horizontal. The bottom of the footing, *AB*, will then be level and it will be easier to get the top of the footing, *CD*, level. The sides of the footing must be perfectly vertical.
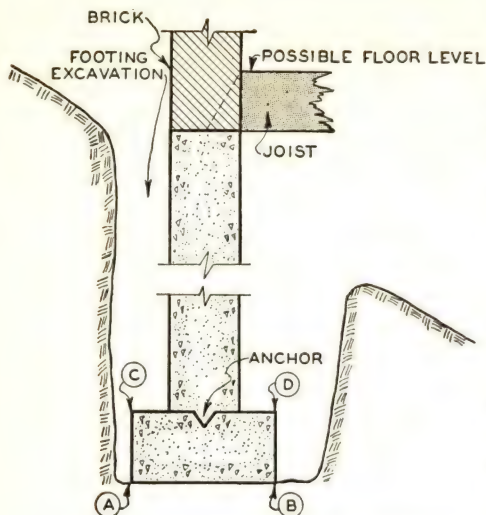
Fig. 4. Footing at Right Angle to Sloping Ground

LEVEL GROUND. Excavations for footings in level ground must be made as carefully as those where the ground sloped. The footings themselves require the same care in both situations.

In (A) and (B) of Fig. 5 are illustrated two examples of careless excavation and lack of forms at the time the concrete was poured. These factors combined to produce footings which were not only of little value but which were actually dangerous. The footing at (A), because of its thin, irregular section, has tilted under the load from the foundation, causing both itself and the foundation to crack, throwing the foundation out of plumb. A condition of this nature might easily cause collapse of a structure. The footing at (B), because of its improper shape, could crack at both places indicated by the arrows. If such cracking occurs, the result would be the same as if no footings had been built.

When footings are required, and in most cases they are, they must be designed

Fig. 5. Improperly Shaped Footings

and built with all the care described and explained in succeeding pages. Any ideas the reader may have regarding the unimportance of footings should be changed at once and all attention given to their proper design and construction.

KINDS OF FOOTINGS

Concrete Footings. The various kinds of footings are classified according to the material from which they are made. For example, the different kinds of concrete footings are described first, then the various types of reinforced footings, the footings made of stone, and finally, brick footings.

CONCRETE FOUNDATION FOOTINGS. Common foundation footings are shown in Figs. 2 and 4. This is the type used most generally for residences, barns, silos, apartment buildings, small stores, or any structure where the loads are not great and where the soil is uniformly dense. If the soil has pockets where it is weaker or less dense, and is not dependable, reinforced concrete footings may be required.
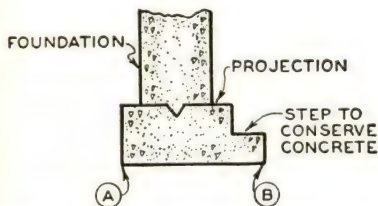
Fig. 6. Stepped-Down Footing for Use When Building Is on Property Line
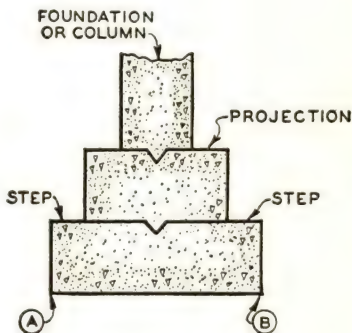
Fig. 7. Stepped-Down Footing

It sometimes happens that a building, as for example a store or apartment building, may be built up to the property line, thus making the use of the kind of footing shown in Fig. 2 impossible. In such instances, a footing as illustrated in Fig. 6 may be used. The required width of the footing is indicated as *AB*. The footing is slightly off center from the foundation. The step is permissible for concrete economy and does not lessen the effectiveness of the footing.

Fig. 7 shows another method of saving concrete when the footing has to be wide. This type requires double the amount of formwork, but in many cases the concrete saving is a distinct advantage.

As previously pointed out, there are instances where, because of the nature of the soil, footings are not absolutely necessary. If the soil is firm enough to permit the omission of forms, the bottom of the trench can be widened as shown in Fig. 8 to form a wider contact point with the soil. This forms a good footing and is an added protection against sinking and cracks.

Fig. 8. Wide Bottom of Foundation Serving as Footing in Firm Ground

Sometimes the footings under old foundations are not below the frost line. As a result, there is alternate heaving and sinking caused by the freezing and thawing of the ground. This condition can be corrected by excavating around and below the old footing and building a new one as illustrated in Fig. 9. This job requires additional foundation as can be seen from the illustration. Work of this kind requires a great deal of labor and material. Moreover, the structure must be supported during the time the new foundation and footing are being constructed. For these reasons, the job should not be undertaken unless the structure is important or unless general remodeling is being done.

In regions where frost is not a consideration, lightweight buildings such as one-story grain bins are sometimes built on a concrete slab, the edges of which have been thickened to form footings. A footing of this kind is shown in Fig. 10. The footing thus formed supports the wall loads and prevents any possibility of the slab's cracking.

Fig. 9. Increasing Depth of Old Foundation

CONCRETE COLUMN FOOTINGS. The most commonly used footing for columns of various materials is the plain square kind shown in Fig. 11. This variety serves the purpose for all types of columns where moderate loads are involved and can be built with a minimum amount of labor, material, and formwork. The

footing shown in Fig. **7** frequently is employed for columns especially where the width, *AB*, must be more than that shown in Fig. **11**.

In large barns one finds either wood or steel columns, depending upon the structural plan and the loads to be supported. Where wood

Fig. 10. Footing for Lightweight Building Where Frost Is Not Present

Fig. 11. Common Column Footing

columns are employed, a combination anchor and footing works out to good advantage. Such a footing is shown in Fig. 12.

Precast, concrete post footings are commonly used for small barns where the loads are not sufficient to require standard foundations and footings. This kind of footing (see Fig. 13) is made from precast con-
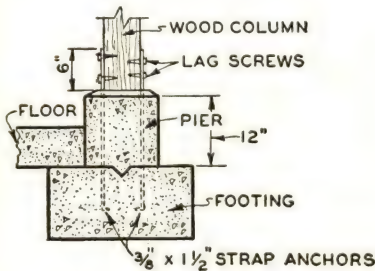
Fig. 12. Method of Anchoring Wood Posts to Footing
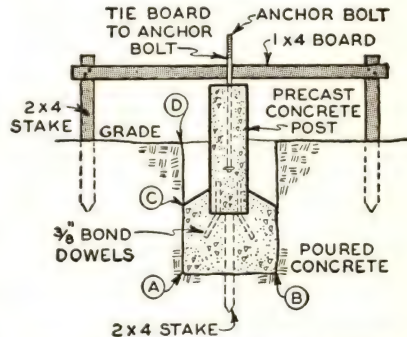
Fig. 13. Precast Concrete Post Footing with Stake Which Prevents Settling

crete posts generally 6″ x 6″ in size, anchor bolts, ⅜″ steel bars, and some poured concrete. In firm soil no forms are required. The 2 x 4 wood stake is used to hold the post in place while the concrete is being poured and is left there until the concrete has had a chance to harden properly. The posts can be cast on the job economically by using simple, three-sided boxes as will be explained in following pages.

CONCRETE CHIMNEY FOOTINGS. Chimneys, especially those built for

fireplaces, weigh a great deal. As a matter of fact, a chimney and fireplace for an ordinary two story residence weighs approximately 30,000 pounds. This concentrated load must be adequately supported not only to safeguard the chimney against cracks and leaning, but to protect the adjoining walls as well. The footing shown in Fig. 14 is the kind generally used where a fireplace and chimney are located in an outside masonry wall. The chimney and wall footings are poured as one. Chimney footings should allow an ample factor of safety and should be used to some extent even on very firm soil.
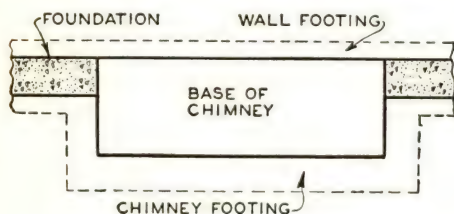
Fig. 14. Footing for Chimney Located in Outside Wall
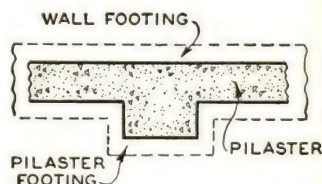
Fig. 15. Concrete Footing for Pilaster

CONCRETE PILASTER FOOTINGS. Pilasters sometimes support heavy loads such as those, for example, from beam ends. Therefore, they must have adequate footings. The shape of the footings for any kind of pilaster, whether it be constructed of brick, concrete, tile, or concrete blocks, should be as shown in Fig. 15.

CONCRETE PORCH AND STAIR FOOTINGS. In many cases the first floor level of a residence is higher than the adjacent street level. This may be due to sloping ground or the need to have the basement floor above the seepage point in the surrounding soil, or because the street sewer is at a shallow depth. In any event, if concrete porches and steps such as shown in Fig. 16 are required, footings *A* and *B* should be at least 6″ concrete walls extending to a depth below the frost line. The footings under the porch should be as shown in the plan view of the porch footing. All three walls should extend to a depth below the frost line. If insufficient footings are built above the frost line, cracks are likely to occur at the locations indicated by *X* in the plan and section views.

The footing under the ends of the steps is important because, unless this footing is sufficient and is carried below the frost line, cracks are apt to occur at the locations denoted by *Y* in the plan and section views.

Porches and steps of the general kind such as shown in Fig. 16 are costly to build in terms of labor and material. Unless they are properly built and with secure footings, they are almost certain to crack and sag. Even in climates where frost is not a consideration, footings to a lesser depth are necessary to prevent settlement or sagging.
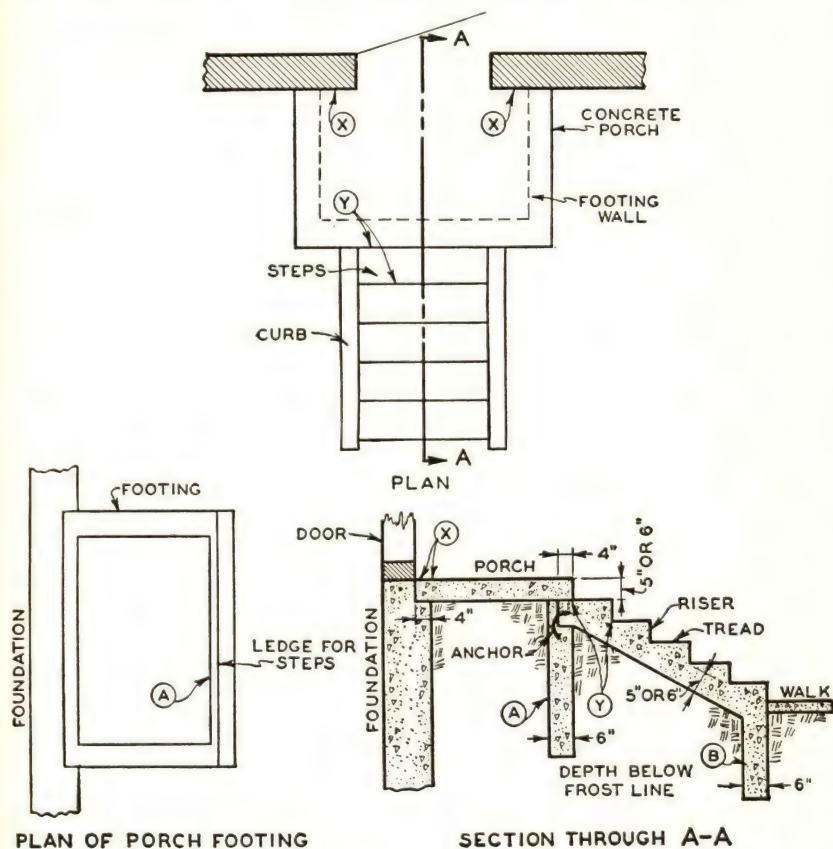
Fig. 16. Footings for Porch and Steps

CONCRETE FOOTINGS UNDER WALL PROJECTIONS. Fig. 17 shows how one wall of a residence has been extended beyond the corner in order to create a pleasing architectural effect in the front elevation. The portion *AB*, or the projecting part of the wall, must have adequate footings just the same as the other walls of the structure. The plan of founda-

tion and footing illustrated in Fig. 17 is an example of one of the best methods of handling a structure of this kind. Note that the portion of the foundation under the projecting wall has a regular footing supporting it. Unless such provisions are made, alternate heaving and sinking due to frost action may cause the projecting wall to crack badly. A
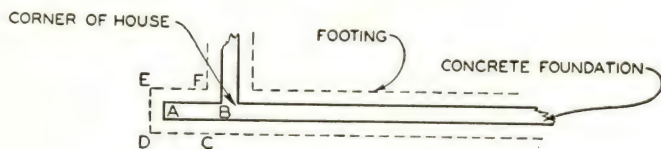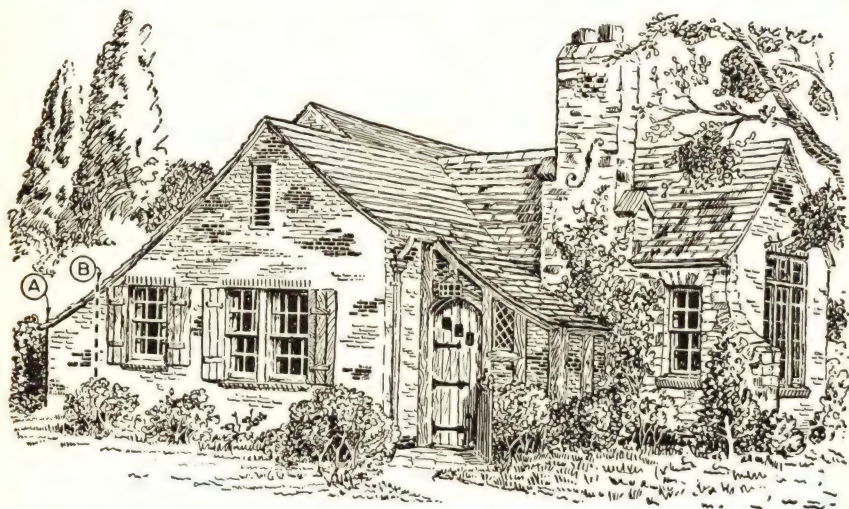
PLAN OF FOUNDATIONS AND FOOTINGS
Fig. 17. Proper Footing under Wall Projection

crack in this section of the wall would be extremely unsightly. In localities where frost need not be considered, the same construction is recommended. However, the foundation and footing need not be more than 2′ 0″ below the surface of the ground. Fulfilling these recommendations may be costly in labor and materials but they result in sound construction and add immeasurably to the durability and structural soundness of a building.

Reinforced Concrete Footings. Ordinarily, reinforced concrete footings are not required for small buildings because the loads are not

great enough to make them necessary. However, for large barns or other buildings where the foundation and column loads are exceedingly large, the use of reinforced concrete provides a stronger footing as well
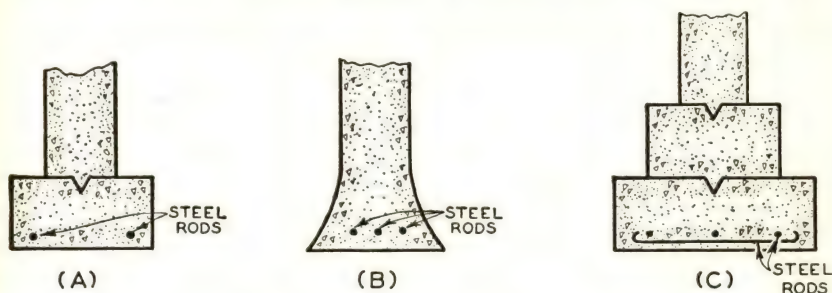
Fig. 18. Reinforced Concrete Footings

as a saving in material cost since a reinforced footing need not be as large as a plain footing because of the relative greater strength of the reinforced concrete.

The footings at (A), (B), and (C) in Fig. 18 are the same types as previously explained except that steel bars have been placed in the concrete to increase its tensile strength.

Stone Footings. Stone footings, as shown in Fig. 19, are seldom used except with stone or rubble foundations. In such cases they are satis-
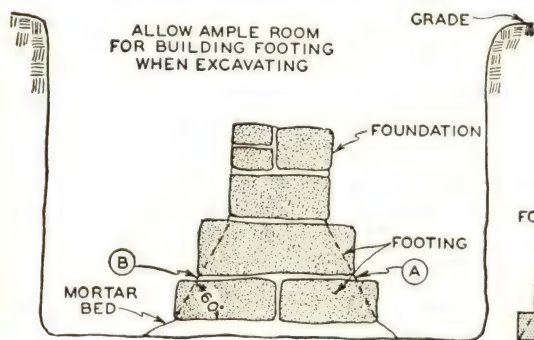
Fig. 19. Foundation Footing of Stone
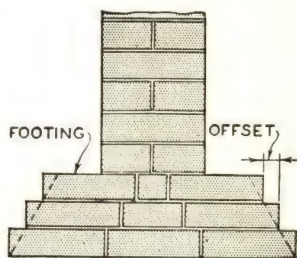
Fig. 20. Foundation Footing of Brick

factory if properly laid in strong mortar. The use of stone footings for column supports is not recommended unless a large, thick, and exceptionally strong piece of stone of the right area can be secured.

Brick Footings. Brick masonry has been used successfully for many years as footings for structures of various sizes and types. Since brick is unaffected by alkali or acid, it may be used in any type of soil. A typical brick footing for use with a brick wall is shown in Fig. 20. Brick footings should always start with a double course at the base. For ordinary loads, offsets may be made in each course as it is laid. Heavier loads require that the offsets or corbeling be made in every second course, the lower course of each being laid in stretcher bond, the upper in header.

DESIGN OF FOOTINGS

Concrete Footings. For ordinary small types of residences and for small, one story store buildings in good firm soil, it is not necessary to do much calculating in order to design the footings. Experience has shown that the following recommendations are safe and satisfactory, providing the soil is firm and not wet, loose, or soft. An examination of the soil on a site can be made with a post auger or by digging down several feet.

CONCRETE FOUNDATION FOOTINGS. The plan view of the small structure in Fig. 21 shows that one side of the building is up against the property line. This requires a footing similar to the one described in connection with Fig. 6. At section *C–C* in Fig. 21, such a footing is shown together with the proper proportions. Suppose that the structure has foundations 10″ thick. Then, according to *C–C* in Fig. 21, *W* is equal to 10″ and ½ *W* is equal to 5 inches. If *X* is assumed to be 3″, then the footing is 20″ wide at the bottom, the projection is 5″, and the step is 5 inches.

The footing for *A–A* in the plan view of Fig. 21 is not on a property line and is similar to the footing illustrated in Figs. 3 and 4. The foundation above *A–A* in Fig. 21 is 10″ thick so the footing is 20″ wide across the bottom, 10″ thick, and has a 5″ projection on both sides.

For larger barns, houses, store buildings, and other structures where the foundation loads are apt to be greater, it is best to calculate the footing sizes according to the following example. The problem involved is to design the footing shown at *A* in Fig. 22. The soil may be assumed to be soft clay.

When calculating footing loads, it is necessary to determine the

total load per lineal foot of the footing. This means that the weight of all structural work must be found, including both live and dead loads from the footing to the top of the structure. Thus, in Fig. 22, the foundation from A to B, the wall from B through C to D, the roof from
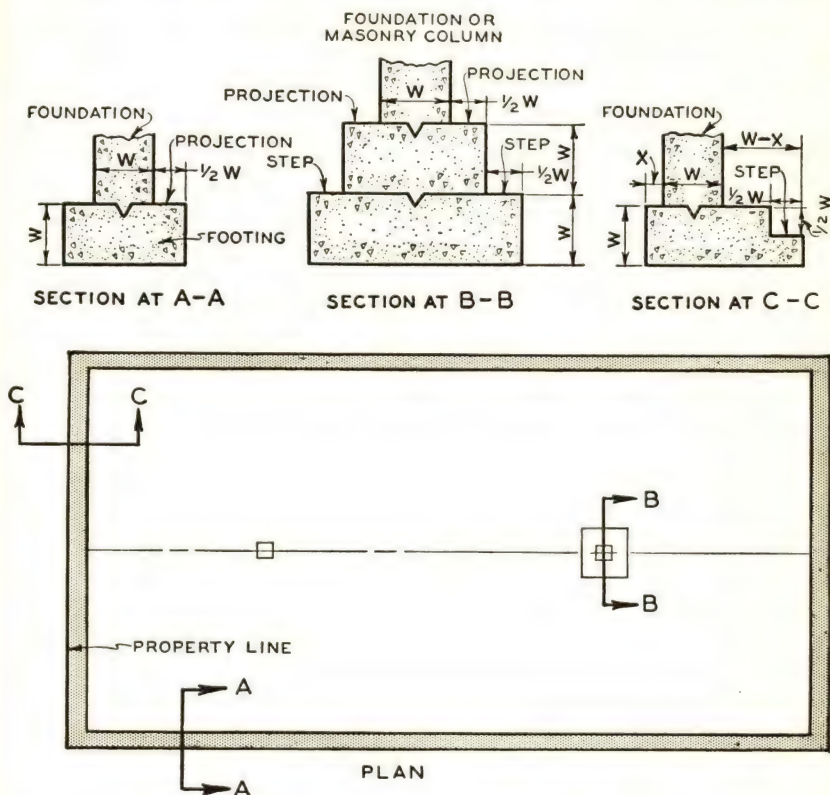
Fig. 21. Proportions for Foundation and Column Footings

D to E, the attic from D to X, the second floor from C to F, and the first floor from B to Y all must be considered.

The concrete for the foundation will weigh 150 pounds per cubic foot. Since the foundation is 10″ wide or almost one foot in width, it is easier when making calculations to think of it as being a full 12″ wide. A section of foundation 1′ 0″ long and 8′ 0″ in height, therefore, will weigh 8×150 or 1,200 pounds.

The masonry material for the wall BD weighs 60 pounds per cubic
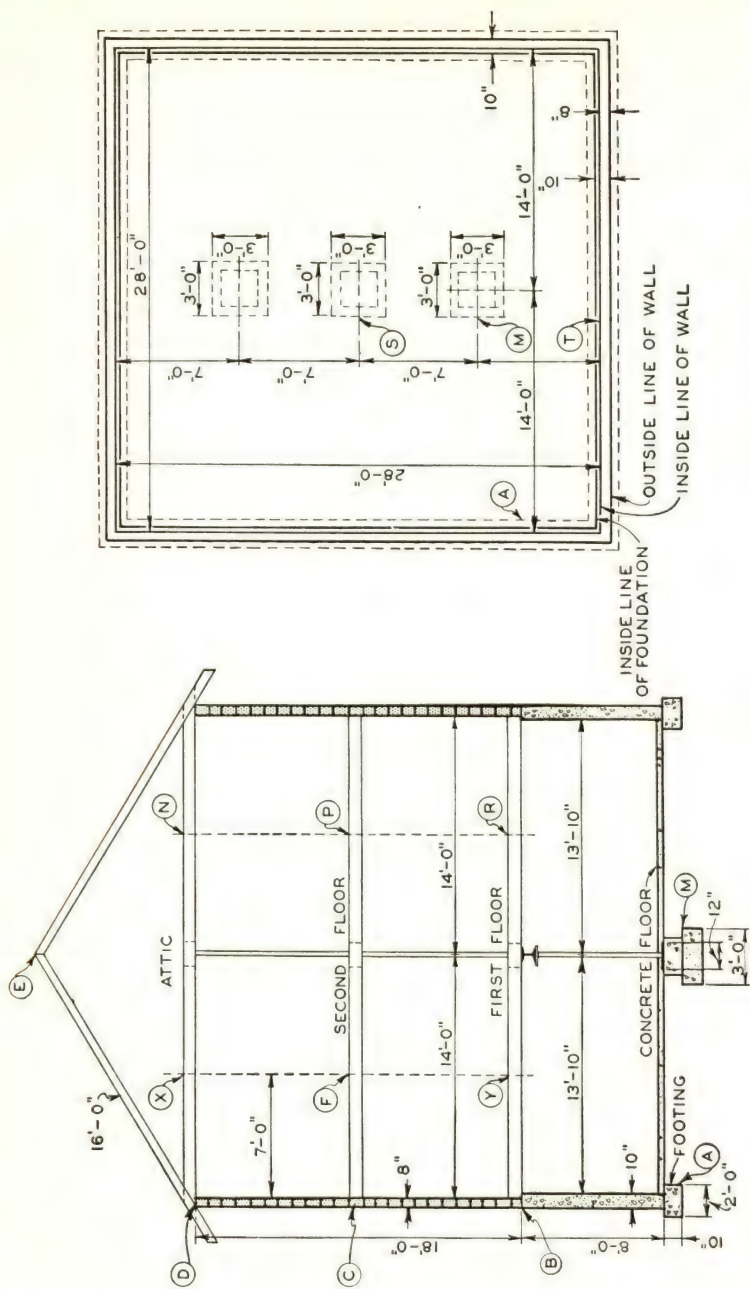
FOUNDATION PLAN

SECTION

Fig. 22. Section and Plan Views of a Two Story Masonry Residence

foot. Since $8'' = \frac{2}{3}$ of one foot, the volume of a section of wall $1'0''$ long, $8''$ wide, and $18'0''$ high would be $18 \times \frac{2}{3}$, or 12 cubic feet. The weight of this section would then be 12×60, or 720 pounds.

If the roof has a combined live and dead load of 35 pounds per square foot and a rafter length of $16'0''$, then the total roof weight for a $1'0''$ length of wall is 16×35, or 560 pounds.

If the attic floor has a combined live and dead load of 56 pounds per square foot and if the span supported by the wall is $7'0''$, then the total floor weight for a $1'0''$ length of wall is 7×56, or 392 pounds.

If the second floor has a combined live and dead load of 60 pounds per square foot and a span of $7'0''$, then the total weight for a $1'0''$ length of wall is 7×60, or 420 pounds.

If the first floor load is assumed as being equal to the load from the second floor, then the complete loading in pounds is as follows:

Foundation load	1,280
Wall load	720
Roof load	560
Attic floor load	392
Second floor load	420
First floor load	420
Total load	3,792

Soft clay soil will not safely support over 2,000 pounds per square foot. The required area of the footing is therefore $3,792 \div 2,000$, or approximately two square feet. Since the weight of the foundation used in the calculations is greater than it actually would be, the two foot area will be adequate. It should be remembered that this area is for one lineal foot of footing.

This footing can be constructed so that it is similar to that shown at *A–A* in Fig. 21. Following the proportions set down in the discussion of Fig. 21, the value of *W* or depth of the footing is 10 inches. Ordinarily, a $5''$ projection on either side of the footing would be sufficient. This would give the footing a width across its bottom of 20 inches. However, the $20''$ is $4''$ short of the $2'0''$ necessary. Increasing the width of the projections to $7''$ will not seriously change the proportions. But if a greater bottom width had been necessary, the thickness would have to be increased in order to keep the ratio of width to thickness about 2 to 1.

Where the soil is strong enough so that little or no footing is re-

quired and where the foundation is not as deep as in the case of structures not having a basement, a wide-bottom foundation such as explained in connection with Fig. 8 is provided for by gradually increasing the width of the foundation at the bottom. Thus, if the foundation is 10″ thick, the widening should start at a point 20″ from the bottom and gradually widen so that it is 20″ across the bottom.

For thickened edges of concrete slabs as explained for Fig. 10, the bottom of the thickened area *AB* is twice the thickness of the slab. The sloping inner side *BC* is usually about 60° although the degree of slope is unimportant so long as it is present. If a footing of this kind is built on soft or weak soil, the weight of the wall above plus a portion of the roof weight must be calculated just as was described for the building in Fig. 22. The distance *AB* should be made sufficiently wide to distribute the load satisfactorily over the soil.

CONCRETE COLUMN FOOTINGS. Since columns represent concentrated loads, footings for them should be designed with the greatest of care. A point to be remembered when considering column footings is that the loads from them will vary much more than will loads from foundations and walls.

Column footings may be simple squares or rectangles, as in Figs. 11 and 12, or they may be stepped as shown in Figs. 7 and 21, if the width across the bottom is great enough to warrant it. The footing shown at *B–B* in Fig. 21 is more often used for columns than it is for foundations. The proportions are similar to those previously explained for the footing in *A–A*. Thus, for masonry columns 12″ square, the value of *W* is 12″, the projection is 6″, the step is 6″, the total height is 24″, and the bottom width 24 inches. When steel columns such as the Lally columns shown in Fig. 11 are used, the width of the bottom plate governs the value of *W*. When wood columns are used, the thickness of the timber governs the value of *W* except where a pier is used as in Fig. 12. In such instances the pier thickness governs the value of *W*.

The following examples are typical of problems which arise when footings are being designed for columns. As a first exercise, suppose it is necessary to calculate the required size for the column footing at *M* in Fig. 22. The same soil condition exists as before and a steel Lally column is to be used.

To the footing at *M* is transmitted the load from one end of the

basement beam running from the column at M to T and one end of the beam running from the column at M to the column at S. Thus, the total floor and partition loads for attic, second, and first floors must be calculated between line XY and NR in the section view, and between T and S in the plan view. The floor spans from X to N, F to P, and Y to R are all 14′ exactly. The distance between S and T in the plan view is 14 feet. The area of each floor to be considered, then, is 14′ × 14′ or 196 square feet. The attic floor load was given as 56 pounds per square foot in the problem involving foundation footings. The total attic floor load which must be supported, then, is 196 × 56 or 10,976 pounds. The second and first floors each have an area of 196 square feet and a floor load of 60 pounds per square foot. The load on each floor is therefore 196 × 60 or 11,760 pounds.

Since the partitions are right over the beam, an approximate weight of 110 pounds per lineal foot will be assumed for them. The partitions on the second and first floors are each 14′ 0″ long. The two partitions add up to 28′ 0″ in length which at 110 pounds per lineal foot amounts to 3,080 pounds.

The total weight in pounds supported by the beams between MT and MS is as follows:

Attic floor load	10,976
Second floor load	11,760
First floor load	11,760
Partition load	3,080
Total load	37,576

Each beam supports half of this load, or 18,788 pounds. The end of each beam transmits half of its load to the column under it. Thus, each beam transmits 9,394 pounds to the column. Therefore, the column at M, in supporting one end of the beam between TM and one end of the beam between MS, has a total load of 18,788 pounds to support.

If the soil can safely support 2,000 pounds per square foot, then the bottom area of the footing must be 18,788 ÷ 2,000, or approximately 9.39 square feet. For ease in calculation, this area can be called an even 9 square feet. This means that the bottom of the footing must be at least 3′ 0″ square.

Following the proportions for the footing B–B in Fig. 21, the value

of W is governed by the plate on which the steel column rests. Assume that this plate is 12″ square. Then with W equal to 12″, the projection will be 6″, the step 6″, the total depth 24″, and the bottom width 36 inches. These proportions work out perfectly.

Some designers cut down somewhat on the floor loads assuming that not all portions of the floor area will have all their maximum live load at the same time. For example, the attic floor load per square foot was
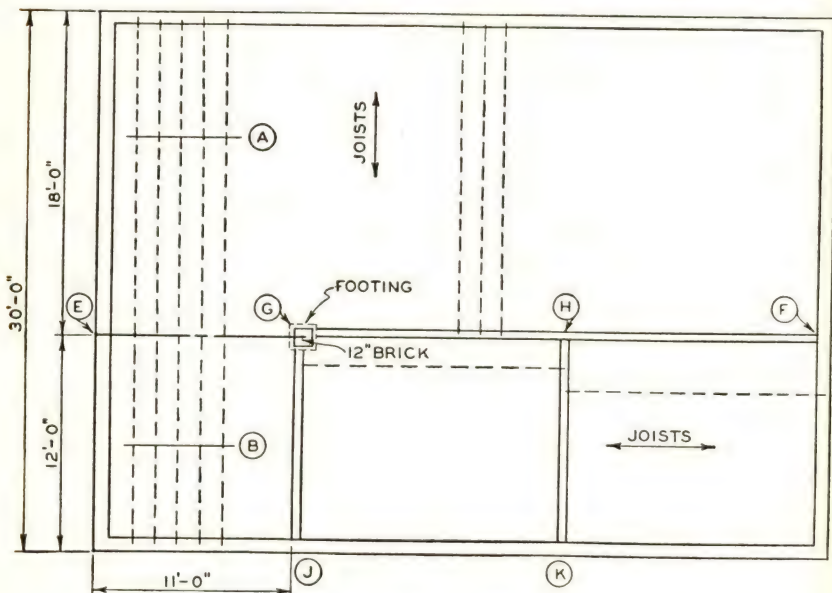
Fig. 23. Plan for Basement Showing Necessity for Brick Column Footing

taken at 56 pounds. Of this, 20 pounds may be considered as dead load and 36 as live. In such calculations, it is always the live load that is cut and the maximum allowable is one-half. The second and first floor loads were calculated on the basis of 60 pounds per square foot. Of this load, 25 pounds is dead load and 35 live load.

The examples in this book use larger than ordinary loads per square foot in order to be on the safe side. The building codes in the various cities specify exact live and dead loads and they can always be used when making calculations.

As a second exercise, suppose it is desired to design the footing for the 12″ by 12″ brick column at G in Fig. 23 assuming that the beam EG

supports 32,000 pounds and that the building site has damp clay and fine, sandy soil. If the beam supports 32,000 pounds, then column G supports one-half of 32,000 pounds, or 16,000 pounds. The brick column is large so its weight should be added to the other load. Brick masonry weighs about 120 pounds per cubic foot. If the column is 7' 0" high and 12" x 12" on the sides, it contains seven cubic feet of masonry materials and weighs 7 × 120, or 840 pounds. The total weight is therefore 16,840 pounds.

If the soil can safely support 4,000 pounds per square foot, the required footing area is 16,840 ÷ 4,000, or approximately 4.21 square feet. This can be called an even four square feet. The footing must be
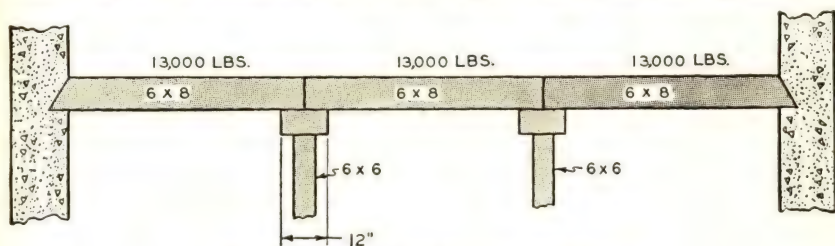
Fig. 24. Typical Wood Beams and Columns

a minimum, then, of two feet square. A simple footing such as shown at A–A in Fig. 21 and having a depth of 12" would be best for this particular problem.

Suppose it is desired to construct the footing for one of the 6" x 6" wood columns shown in Fig. 24. The soil can be assumed to be capable of supporting 4,000 pounds per square foot. Each column supports two beam ends. If each beam end transmits 6,500 pounds to the column on which it rests, each column, therefore, must support 13,000 pounds. The area necessary to support this weight is 13,000 ÷ 4,000, or 3.25 square feet. To determine the dimensions of the sides of this footing, the square root of 3.25 is found. This is 1.8 feet which is about 1' 9" as the dimension of the side. A simple footing like that at A–A in Fig. 21 can be used. The depth should be about 12 inches.

Suppose it is desired to build the footings for the 5" O.D. Lally columns in Fig. 25, each of which supports a 35,808 pound load. If the damp, clay soil can safely support 6,000 pounds per square foot, the necessary footing area will be 35,808 ÷ 4,000, or 8.65 square feet. For

ease in calculation, this can be called an even 9 square feet. The footing will then be 3 feet square. It could be stepped as is the footing in *B–B* of Fig. 21 or a simple footing like that in *A–A* could be used with a thickness of 18 inches.
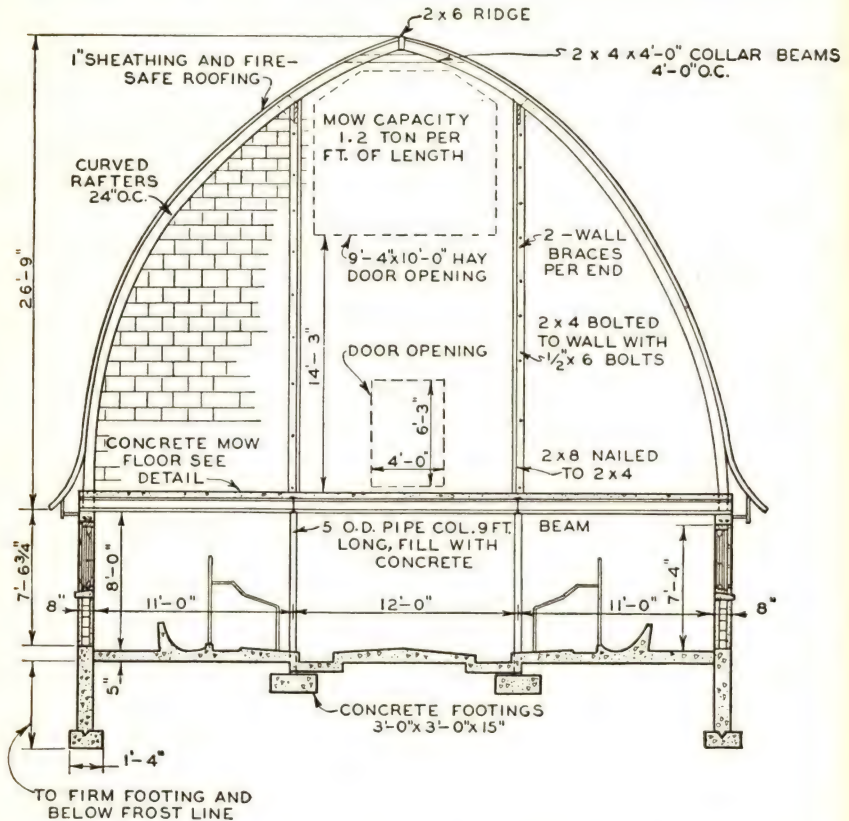
Fig. 25. Section of Dairy Barn Showing Haymow Floor and Columns

For precast concrete post footings such as those shown in Fig. 13, the required bottom width, *AB*, can be determined in exactly the same manner as explained for more complicated structures. Depth *AC* can be equal to or somewhat greater than *AB*. Depth *DA* should be from 3′ 0″ to 4′ 0″ at most, depending upon the frost level. The heavier the poured concrete block, the more stability the supported structure has against windstorms and the like. The precast post can be made

6″ x 6″ or 8″ x 8″ depending on the beams to be supported. Either size will work out satisfactorily for light structures. Precast posts are generally made about 4′ 0″ long. A 6″ x 6″ post of that length weighs 145 pounds, whereas the 8″ x 8″ post weighs about 260 pounds. It is well to consider the weight of the post when designing the bottom dimension *AB*.

CONCRETE CHIMNEY FOOTINGS. Chimney footings are designed like column footings except that simple footings are always used. The weight of a chimney is calculated by figuring the number of cubic feet of brick in the structure and multiplying that figure by 120 pounds.
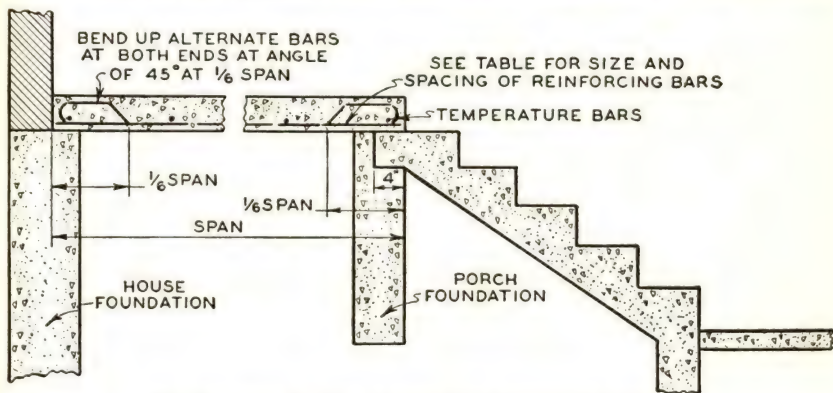
Fig. 26. Cross Section of Reinforced Concrete Porch Floor

The weight of the tile flue lining also should be considered. An ordinary two-flue chimney having a small vent for a gas heater and one fireplace in a two story house should weigh between 35,000 and 45,000 pounds.

In order to understand the design of chimney footings, assume that it is necessary to construct the footing for the chimney shown in Fig. 14. If the weight of the chimney is given at 35,000 pounds and the soil's degree of firmness allows it to support up to 2,000 pounds per square foot, the required footing area will be 35,000 ÷ 2,000, or 12.5 square feet. If the chimney measures 6′ 0″ x 2′ 0″, or 12 square feet, little or no footing will be needed. However, in order to make a firm base upon which to build the chimney and to guard against any possible settlement and resultant cracks, the foundation footing (see Fig. 14) should be enlarged so that it extends beyond the chimney base at

least 6″ and preferably 8 inches. For the sake of convenience, the depth can be made the same as the foundation footing.

CONCRETE PILASTER FOOTINGS. Such footings are designed exactly as were chimney footings and should also be a part of the foundation footings.

CONCRETE PORCH AND STAIR FOOTINGS. When the porch floor is supported by the earth underneath it, no reinforcing is necessary. A recommended construction is shown in Fig. 16. If there is no earth fill or if the fill cannot be depended upon, then the floor should be reinforced as shown in Fig. 26. The size and spacing of the reinforcing bars necessary for porch slabs of varying spans and thicknesses are given in Table II.

TABLE II. REINFORCING BARS REQUIRED FOR PORCH SLABS

SPAN	THICKNESS	SIZE OF BARS	SPACING OF BARS
4′0″	4½″	¼″	8″
5′0″	4½″	¼″	6″
6′0″	4½″	⅜″	9″
8′0″	5″	⅜″	6″
10′0″	5″	⅜″	4″

The slab for concrete cast-in-place steps should be 5″ to 6″ thick as shown in Fig. 16. The top of the slab should have bearing on wall A to prevent the possibility of any movement taking place. Walls A and B should have a depth to below the frost line or, where frost does not have to be considered, at least 2′0″ below ground surface. These walls should be at least 6″ thick. Wall B should be poured at the same time as the stair slab. The risers in such stairs should have a certain relation to the width of the treads and at the same time should not be more than 6″ to 7½″ in height. For exterior steps, low risers and broad treads are generally preferable. The tread should be about 10″ for a comfortable flight of steps. Curbs should be from 6″ to 10″ in width.

CONCRETE FOOTINGS UNDER WALL PROJECTIONS. Under such walls as shown in Fig. 17, the foundation should be the same depth and thickness as the regular foundation. It should be poured at the same time also. In other words, it should be a part of the main foundation. The footing, $EFDC$, should be the same size as the regular foundation footing. In localities where frost need not be considered, the section

AB can be of considerably less depth but the footing should remain the same size. To provide footings for walls of this kind is difficult, but unless the footing is properly built, cracks are almost certain to develop.

Reinforced Concrete Footings. The design of this type of footing requires the use of intricate mathematics and is not explained here for that reason. Whenever reinforced footings are thought necessary, a structural engineer should be consulted.

Stone Footings. Using good strong stones and Portland cement mortar, a footing such as shown in Fig. 19 can be built successfully. The same factors govern the construction of stone footings as those discussed regarding footings built of concrete. Stone footings, unless very large, are usually restricted to small structure or residential use where no great loads are encountered and where the soil is found to be consistently firm.

Brick Footings. Hard-burned bricks and Portland cement mortar are used in the construction of brick footings. The bottom areas of brick footings are calculated in the same manner as are the bottom areas for concrete footings. For light loads from foundations not over 8″ in width, a footing such as shown in Fig. 20 may be used. For heavier loads and thicker walls, reinforced brick masonry should be used, designed by a structural engineer.

HOW TO BUILD FOOTINGS

The building of footings is every bit as important as their design. If they are not built exactly right, their usefulness will be greatly lessened. It is not difficult to build good footings if the following suggestions and simple directions are incorporated into every such project.

Concrete Footings. Forms for concrete footings are fully described in the chapter on formwork.

CONCRETE FOUNDATION FOOTINGS. Where footings similar to those shown in Figs. 2, 7, 21, and 22 are to be built, the procedures used are somewhat as follows:

The first item confronting the mason in the building of footings and foundations for a new building is the excavation. In standard practice, the depth at which the footings are placed determines the

depth of the basement. For this reason, the depth of the excavation must be determined exactly before any work is done.

Fig. 27 is a section view of a typical residence showing the first floor, basement, foundation and footing, basement beam and column, and the basement floor. Generally, architects show a dimension on their blueprints to indicate the distance from the surface of the basement floor to the surface of the first floor. This is dimension A in Fig. 27. From this dimension, the depth of the excavation can be easily
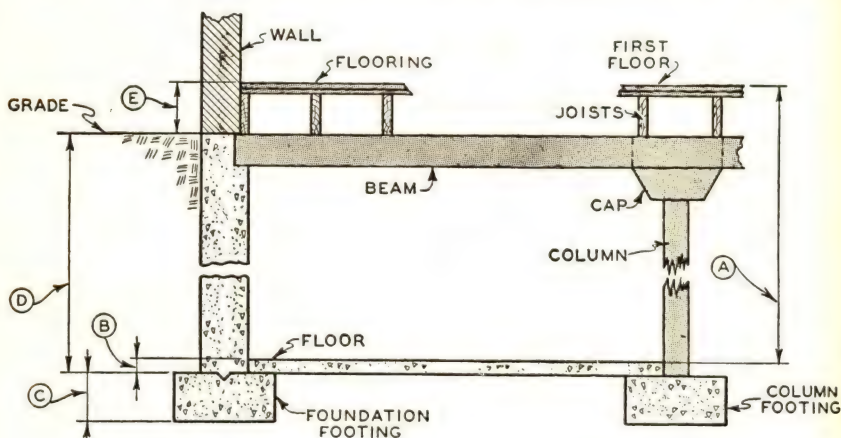
Fig. 27. How to Determine Depth of Excavation

determined. To find this depth, study dimensions A, B, C, D, and E. Dimension E shows the height of the first floor level above the grade or ground level. Subtracting dimension E from dimension A gives the depth below ground level of the surface of the basement floor. To this must be added dimension B, the thickness of the basement floor. The figure obtained is dimension D which is the distance between the ground level and the top of the footing. The excavation should then be made to a depth equal to dimension D.

In firm soil, the sides of the excavation need not have much, if any, slope. (See Fig. 28.) However, if the soil is loose or apt to cave in, the slope must be increased to the point where no sliding or caving can take place. Generally speaking, the excavation is made about 2′ 0″ larger than the length and width of the basement. This is to provide room for putting in the formwork for the footing and foundation. If the topsoil

is rich, the first **12"** to **18"** is usually stored in one corner of the building site to be used in landscaping after all construction work has been completed.

The bottom of the excavation must be level. This can be determined by selecting a 2 x 6 plank several feet in length which has straight, parallel edges. The plank is placed on edge at various points in the bottom of the excavation and the mason's level laid along the top edge of the plank. In this manner, the level of the excavation can be checked and any irregularities corrected. This should be done carefully because if the bottom is not level, difficulties will begin to occur as soon as the formwork for the footings is started.
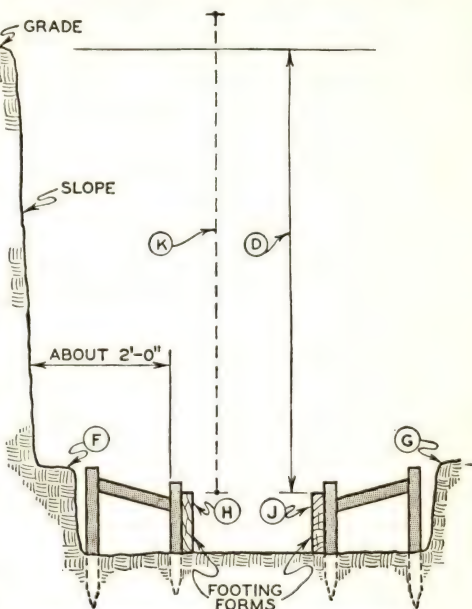
Fig. 28. Method of Locating Placement of Foundation Footing

The location for farm buildings and similar structures need not be determined with the degree of accuracy necessary when building residences. It is important that homes be located on the most advantageous spot on the building site. Carelessness in establishing an exact location might easily result in local building code infringement or extension of a structure over the neighbor's property line. As insurance against such accidents, the city or county surveyor usually is called in to locate the boundaries of the building to be erected.

Once these boundaries have been established, the excavation lines are laid out. A good method of accomplishing this is shown in Fig. 29. Small stakes are located, first, at each corner of the residence. Tacks are driven into the tops of the stakes to indicate the outside lines of the excavation. As a check on the squareness of the corners, measure the diagonals to see if they are all equal. The squareness of any one corner can be checked by measuring down one line for **6′ 0″**

and down the other for 8′ 0″. The diagonal across these two end points will measure 10′ 0″ if the corner is truly square.

After the corners have been located and squared, three 2 x 4 stakes of a suitable length are driven into the ground at each corner as shown in Fig. 29. After this has been done, 1 x 6 boards are nailed horizontally so that their top edges are all level and at the same grade. A cord is now held across the tops of opposite boards at two corners and adjusted so that it will be exactly over the heads of the tacks in the
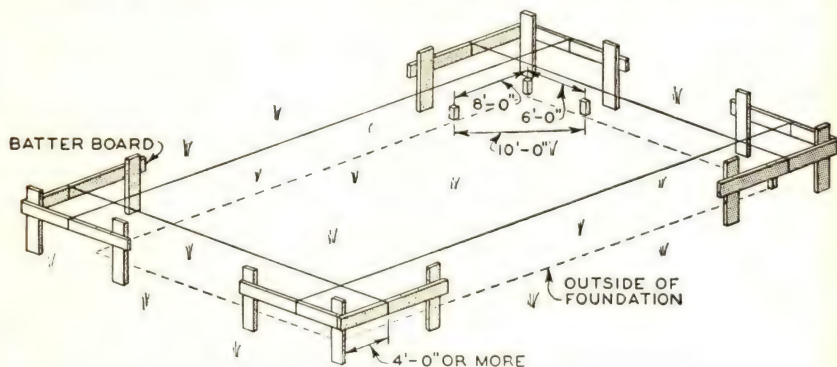
Fig. 29. Method of Laying Out Excavation for a Building

two corner stakes. Saw scarfs ¼″ deep are cut where the line touches the boards so that lines may be easily replaced if they are broken or disturbed in any way. After similar cuts have been made in all eight batter boards and the lines strung in position, the lines of the excavation will have been accurately established.

The dotted line *K* in Fig. 28 shows the outside edge of the foundation. This is also indicated in Fig. 29. The footing excavation can be exactly located by use of a plumb bob placed in the position of line *K* in Fig. 28. If the footing extends 4″ beyond the foundation, then form *H* is placed that distance beyond the plumb bob.

The depth of the footing excavation is equal to dimension *C* in Fig. 27, or as designed. Sides *F* and *G* of the footing excavation (see Fig. 28) should be made sufficiently far apart to allow room for the stakes and formwork as illustrated in Fig. 30. The bottom of the footing excavation must be flat and horizontal and the soil must be carefully removed so that the bottom is undisturbed. The top of the

footing must be level. This can be checked by using the mason's level, placing it along the top of each board, as in H and J in Fig. 28 and at frequent intervals across the forms.

The concrete mixes recommended for footings are 1:3:5 or $1:2\frac{1}{4}:4$. In general, the 1:3:5 mix should be suitable for all plain concrete foot-

Fig. 30. Freshly Poured Concrete Is Spaded to Remove Voids
Courtesy of Portland Cement Association

ings. Not more than five gallons of water should be used per sack of cement. For reinforced concrete footings, a mix of $1:2\frac{1}{2}:3\frac{1}{2}$ is recommended. A trial mix can be made as a means of obtaining a stiff concrete, adding sand or gravel if the mix is too wet.

It is necessary to pour the concrete for the footing in one continuous operation to get the benefits of a solid piece of masonry. The concrete should be placed in the forms in thin layers and spaded care-

fully next to the forms. A **V** shaped piece of wood having sides about 2″ wide can be placed at the top of the footing while the concrete is being placed to provide the anchor groove or key for the foundation. This is shown in Fig. 4. The tops of the footings should be made smooth and perfectly level between the forms.

In warm weather forms for the foundation can be set in place two or three days after the footings are poured. The footing forms can be safely removed in three or four days. During cold weather the footings should not be loaded or have their forms removed for at least seven to ten days.

The construction for stepped footings such as shown in Fig. 3 is essentially the same as for other footings. However, the footings under the unexcavated section of the building are constructed similarly to those illustrated in Fig. 4. The depth of these footings, a type generally used under unexcavated portions of residences and barns, depends mainly on its being below the frost level.

A wide bottom footing such as illustrated in Fig. 8 requires no forms because it is not used unless the soil is firm and capable of supporting the foundation load without regular footings. Such footings can only be constructed if their depth is shallow because the trench for them must be excavated to exact dimensions. The widened section is created by using a spade to enlarge the trench at the bottom. The bottom should be flat and the concrete should be placed on undisturbed soil. Use a 1:3:5 or 1:2:4 mix of concrete not as stiff as for regular footings. It should be placed in layers of about 6″ to 8″ thick at a time and spaded carefully to insure no voids being left anywhere. Such foundations can be loaded in about one week in warm weather and two weeks in cold weather. If pouring cannot be completed in one day, a device similar to that shown in Fig. 31 can be used. This provides a key which locks one day's pouring to that done the next day.
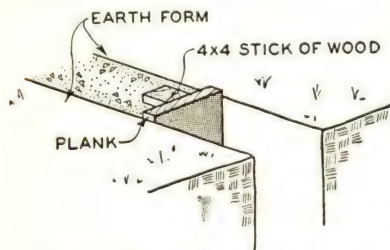
Fig. 31. Form Stop Used at End of Day's Pouring

When a new and deeper footing is necessary, the method of construction is as shown in Fig. 9. The old foundation must be held

up by jacks or shoring. A wide trench is excavated to the correct depth to one side and under the old footing. If the soil is firm, the sides A, C, and D can be used in place of forms. In loose soil, a great deal more excavating must be done to get forms in at A and C. The forms at B and E are made of 2 x 4's, and 1 x 4 and 1 x 6 boards, all supported as indicated. The extension of the old footing should be cut off with a heavy hammer and chisel. The boards in the form are not put into place near the top until the concrete has been placed that far up. A rather wet mix of 1:3:5 concrete should be used and this should be well spaded. Near the top the concrete must be rather stiff in order to allow it to be pushed into place under the old footing.
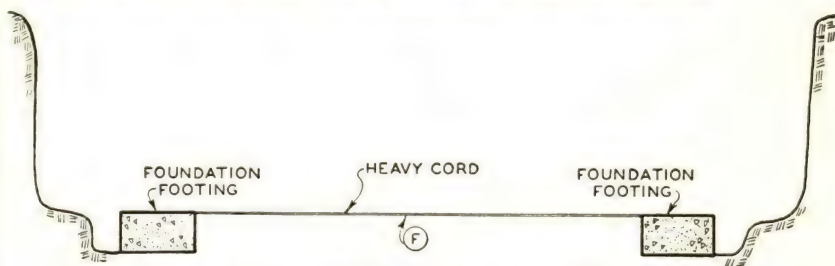
Fig. 32. Method of Determining Level for Column Footing

Forms can be removed after three or four days in warm weather but not for at least a week or ten days when it is cold. The new concrete should not be loaded for from three to four weeks in warm weather, and in cold weather at least four weeks must go by before the concrete can be used.

When building a combination footing and floor slab such as shown in Fig. 10, the ground should be leveled off perfectly. The forms can be made of 2 x 8, 2 x 10, or 2 x 12 planks to form the height AD. The gravel can be placed and the slope BC roughly shaped. Use a concrete mix of $1:2\frac{1}{2}:3$ in a stiff state. Place the concrete first around the edges to form the footing, then fill in the center portion of the slab. Tamp carefully to make certain all voids have been filled. The forms can be removed in two or three days in warm weather or after a week or more during cold weather. The masonry wall can be built after two or three weeks in warm weather or after three or four weeks in cold.

CONCRETE COLUMN FOOTINGS. The top level of column footings for residences and other small buildings can easily be determined.

When the foundation footings have been placed as previously described, a heavy line or cord is stretched from one footing to the other as shown in Fig. 32. This line will determine the footing top at any point, as for example at *F*.

The excavation for column footings is exactly the same as was described for foundation footings except that it is not necessary to do the excavating along the sides for form clearance. To build footings such as shown in Fig. 11, the excavation and forms are made so that they are similar to those shown in Fig. 7 of Chapter I. The same concrete mixes are recommended as were used for foundation footings. The concrete should be stiff and should be spaded carefully, especially around the sides of the formwork.

The building of footings such as shown in Fig. 12 for use in barns is greatly similar to other footings. The depth is generally not more than a few inches under the barn floor. The same concrete mix recommended for foundation footings is used in a stiff state to prevent it from running. The strap anchors can be made any length required by the local blacksmith. They should be drilled for the screws at the top and bent at the bottom. The top surface of the pier should be slightly beveled and troweled smooth. The forms can be removed after three days in warm weather and from six to seven days in cold. The footing should not be used to support any weight for at least two weeks in warm weather and at least four in cold.

Precast concrete post footings (see Fig. 13) are simple to make. In firm soil, the sides of the excavation serve nicely as forms. If the soil is very loose, rough, boxlike forms can be made easily. In either event, 2 x 4 stakes are driven far enough into the ground to provide support for the precast post. They must be high enough above ground so that a 1 x 4 nailed between them at their tops can be used as a steadying board to which the anchor bolt of the concrete post is tied. The post is then held exactly in position until the footing has had a chance to set. The concrete mix should be fairly stiff, a 1:3:5 ratio, and should be carefully spaded to make certain that it finds its way directly under the post. The braces for holding the post in position can be removed after two days in warm weather and after a week during cold. The post can be partially loaded after a week in warm weather and after two or three weeks in cold weather.

A simple, three-sided box is used to cast the concrete posts as shown in Fig. 33. The ends of the box should be provided with clamps or screws so that they can be easily removed when the concrete has set. Their removal is necessary because of the $\frac{3}{8}''$ dowel bars and the anchor bolt. A concrete mix of $1:2\frac{1}{2}:3$ should be used in a stiff state. Fill the form half full, then place the dowels and anchor bolt so that their ends are protruding through the holes in the ends

Fig. 33. Form for Precast Concrete Post

of the form. Care should be taken to see that the anchor bolt is straight so that it will be vertical when the post is in a vertical position. The balance of the concrete is poured and the whole spaded carefully. The post should be cast only in warm weather and can be removed from the form within two or three days. To remove the forms, the ends are slid off, care being taken not to put pressure on the dowels or anchor bolt. Posts of this kind can be cured by placing them in a bed of sand or soft, moist soil where they are left for 28 days. After this length of time they can be used.

CONCRETE CHIMNEY FOOTINGS. Generally speaking, chimney and fireplace footings need not be any thicker than foundation footings and are usually at the same level. Therefore, the foundation footing forms need only be extended to the required width. The foundation and chimney forms are then poured at the same time as described for foundation footings.

CONCRETE PILASTER FOOTINGS. Footings for concrete pilasters are prepared and poured in the same manner as described for chimney footings.

CONCRETE FOOTINGS UNDER WALL PROJECTIONS. The procedures for constructing formwork and pouring wall projection footings are the same as described for foundation footings.

For footings in the form of walls such as A and B in Fig. 16, the excavation sides made be used for forms where the soil is firm. Otherwise, the excavation must be made at least 2' 0" wide and regular foundation forms used. The steps should be poured at the same time as footing B.

Care should be taken to see that the bottoms of the excavations are square or level and that the concrete is placed on undisturbed soil. The same concrete mix as recommended for foundation footings can be used. If forms are used, they can be removed in two or three days in warm weather and in a week in cold weather. Just as soon as the forms are removed, the soil should be backfilled. These footings can be loaded within a week or two in warm weather and from two to three weeks in cold.

Reinforced Concrete Footings. What has been explained in the foregoing material pertaining to plain concrete footings applies equally well in all respects to reinforced concrete footings. In reinforced concrete, the reinforcing rods are placed from 1½″ to 3″ from the bottom of the footings. This is done by placing that much concrete in the form first, then laying the rods in place after which the balance of the concrete is poured.

Stone Footings. For stone footings such as shown in Fig. 19, the depth is determined and the excavation made as previously described for concrete footings. The soil surface must be smooth, absolutely level, and undisturbed. The mortar used should be a 1:3 mix. The two stones next to the ground should be flat with top and bottom parallel so that there is no chance for them to rock. Before lifting the bottom stones into place, a thin bed of mortar should be spread over the soil. The stones should then be worked about until a firm, solid bedding has been made. Next, pour thinned mortar into the joint between the two stones to fill completely the joint space. The stones should be wet when put into place. Before the stone for the second course is lifted into position, a mortar bed is spread thick enough to insure a bedding for all points on both surfaces of the two stones. The joints at *A* and *B* should be carefully pointed.

Brick Footings. For brick footings such as shown in Fig. 20, the depth, excavation, etc., are carried on exactly as described in conjunction with concrete footings.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. Why column footings are sometimes thicker and wider than foundation footings?

Answer. Because they support floor and partition loads over a considerable area and thus have much greater concentrated loads per square foot than foundation footings.

2. What the recommended ratio between the bottom width and thickness is for foundation footings?

Answer. 2 to 1. In other words, if the bottom width is 24″, the thickness should be 12 inches.

3. What two factors determine the depth below ground level at which foundation footings must be placed?

Answer. The distance between the surfaces of the basement and first floors and the frost level.

4. What is probably the greatest frost depth in the United States?

Answer. 72 inches.

5. Why foundation footings must be square on the bottom?

Answer. To prevent the footing from cracking or allowing the foundation to settle to one side or the other.

6. Why footings must be well below the frost line?

Answer. To prevent heaving and settlement as the frost comes and goes.

7. How long small-dimension, precast concrete items such as posts should be cured?

Answer. At least 28 days.

8. Why concrete porches and exterior steps sometimes crack to the point of being unsightly and even dangerous?

Answer. Because they have insufficient footings. Insufficient footings allow settlement which, in turn, causes cracks.

9. What the two main advantages of reinforced concrete footings are?

Answer. Less concrete is required and they are stronger than plain concrete footings.

10. What the advantage is of a stepped column footing?

Answer. Saving in material.

11. How some designers cut down on the sizes of footings required?

Answer. By using only half of the specified live load.

12. What principle designers follow when they use only half of the specified live loads?

Answer. The principle that probably not more than half of the floor areas involved will ever have to support their full live load at any one time.

13. How the bottom width of a precast concrete post footing is determined?

Answer. In exactly the same manner as explained for regular column footings.

14. What the purpose is of the V in the footing shown in Fig. 2?

Answer. This **V** keys the foundation to the footing and prevents any possibility of the foundation sliding off the footing.

15. What general relation should exist between the risers and treads when designing concrete steps?

Answer. Low risers and broad treads are best.

16. Why a mortar bed is placed on the soil before the first stones of a stone footing are laid?

Answer. To provide a good bedding for the stones and to prevent their rocking.

17. Why holes are necessary in the ends of the forms for making precast concrete posts?

Answer. Because of the dowels and the anchor, both of which protrude from the ends of the post.

REVIEW QUESTIONS

1. Explain the theory of footings.

2. Explain how to calculate the total load per lineal foot on a residence foundation footing.

3. How many pounds per square foot can dry sand support safely?

4. Why are some foundations widened at the bottom even though the soil seems strong enough to support the load?

5. Design the footing for partition GF, in Fig. 23, assuming a combined live and dead floor load of 60 pounds per square foot, that only the first floor has to be supported, and that the soil has a strength of 4,000 pounds per square foot.

6. What is the weight of a two-flue chimney and fireplace likely to be?

7. What height risers are permissible for outside concrete steps?

8. What kind of a foundation footing can be used when one side of a building is up to the property line?

9. What feature of a Lally column is considered in determining the width of its footing?

10. How is a precast post held properly in place while its concrete footing is poured and drying?

11. What are batter boards used for?

12. Explain the method of laying out the excavation for a building.

13. Explain how concrete is placed in the forms for a foundation footing.

14. Explain what to do in the event a wall type footing could not all be poured in one day.

15. Explain how to determine the level for a column footing.

16. Explain the method of stepping wall footings in sloping ground.

17. Through what is the load from a Lally column transmitted to its footing?

CHAPTER III

Foundations and Waterproofing

QUESTIONS CHAPTER III WILL ANSWER FOR YOU

1. *What are some of the more common materials used in the construction of foundations?*
2. *What are the factors governing the design of foundations?*
3. *What are the important points to be remembered when building foundations?*
4. *What features of a foundation render it ratproof and termite free?*
5. *What are the reasons necessitating the waterproofing of foundation?*

INTRODUCTION TO CHAPTER III

Because the foundations of most small buildings are concealed from view except for a short period during construction, there is a marked tendency to overlook the importance of the foundation and its relation to the visible portion of the structure. The stability and permanence of any building are directly dependent upon its proper construction. A poorly made foundation with its consequent unequal settling, tilting, and fracturing, almost always results in an endless series of bills for cracked ceilings and walls and sagging door and window frames.

If it were possible to find a locality in which ideal building conditions existed, and if a basement were not desired in the structure being erected, it might be practicable to construct small buildings without first providing a true foundation. Because a soil firm enough to support the weight of a building is a rarity, and since most construction in this country is in areas which are affected by frost, the possibility of such foundationless building is hardly worth consideration.

In addition to the protection offered against frost action and the provision for a firm, unyielding base on which to build, a foundation serves to support the framework off the ground. This is essential because the moisture content of the soil would cause premature deterioration of such woodwork. Also, contact with the earth would invite infestation by termites which is another important problem that is solved through the use of foundations. A final advantage of the foundation is the barrier it offers to water which, in the absence of a foundation, would seep into the rooms or spaces under the house.

Although it is possible to achieve an almost completely waterproof concrete when desired through accurate proportioning and careful mixing of the proper ingredients, the usual procedure, where a truly waterproof foundation is a necessity, is to treat the exterior wall of the foundation with a waterproofing compound. There are a variety of these materials and methods and
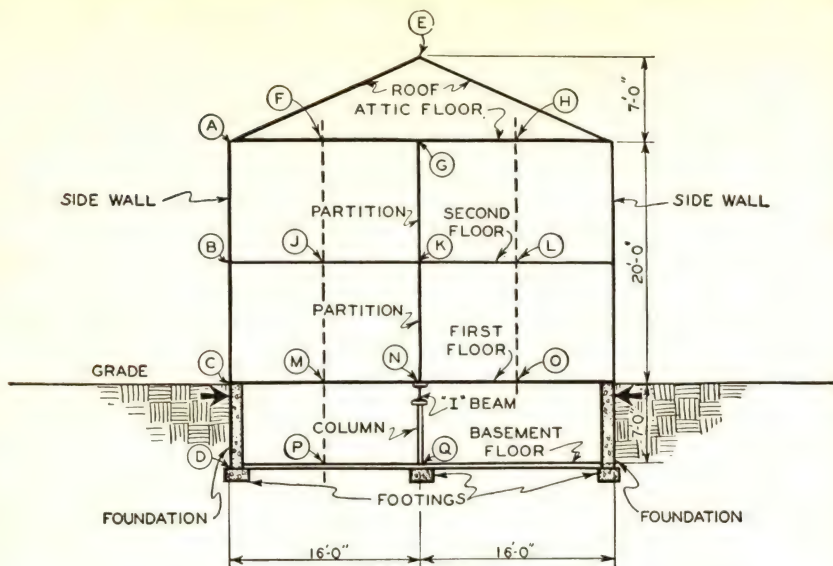
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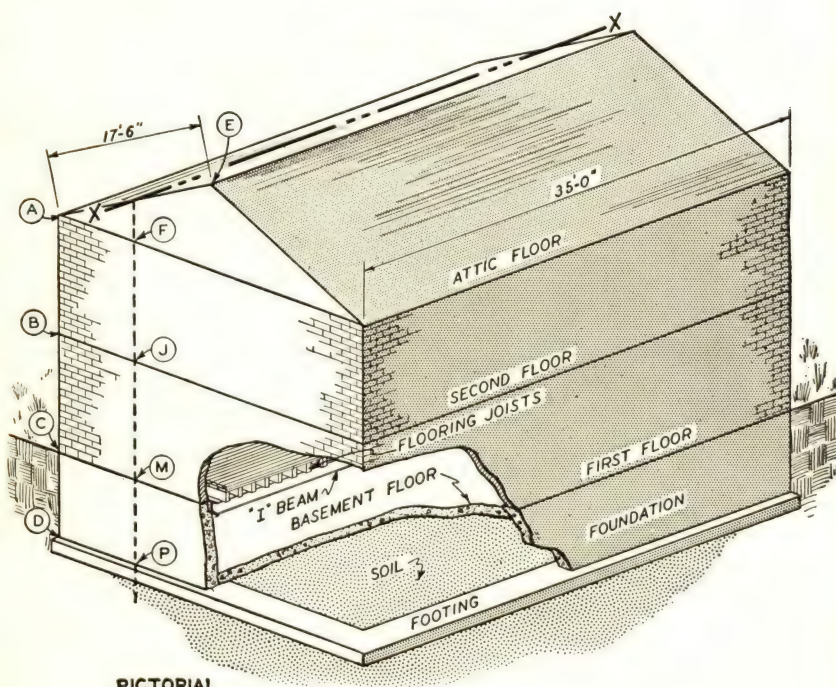
PICTORIAL VIEW

Fig. 1. A Residence and the Foundation Supporting It

a complete description of them is given in the latter portion of the chapter.

These are but a few of the vital points regarding foundations and their waterproofing which you will find discussed in this chapter. It is essential that the importance of the foundation as an integral part of any structure in which it is found be recognized at once. This is the key to the understanding of this significant chapter.

NECESSITY OF FOUNDATIONS

It is an incontestable fact that no worth-while endeavor can be pushed to successful completion unless it is based on sound principles. There is a close parallel to this truism in the field of masonry. No building of any size will be a success unless it is built on a firm, adequate foundation. Good design, good construction, and the factors controlling these conditions are explained and illustrated in the pages that follow. Foundations are one of the most important aspects of masonry work and for this reason deserve careful study.

THEORY OF FOUNDATIONS

The theory of foundations can be explained most easily through a careful consideration of the important purposes they serve. A study of the following functions performed by foundations will demonstrate that the cost of properly designed and carefully built foundations is an excellent investment. Any attempt at cutting the cost of construction of such foundations will prove to be false economy.

Foundations Provide Support. In all structural work the question of proper support must be considered constantly because every part of any building depends upon some other part or parts of the same building for its own support. For example, the roof of a two story residence is usually supported by two or more outside walls. Portions of the attic, second, and first floors are also supported by the outside walls. These walls are in turn supported by the foundations. The important part played by the foundation in supporting this weight can be much better understood by studying Figs. 1 and 2. The section drawing in Fig. 1 shows the roof, outside walls, floors, partitions, and foundations for a residence. The pictorial view indicates those same items plus a cutaway which shows part of the basement and first floor in section. From both views it can be seen that the roof is supported by the outside walls. For example, one-half of the roof, or *AE*, is supported by the outside wall *AC*. The other half of the roof

is supported by the opposite outside wall. Partition *GK* supports the attic floor between points *F* and *H*. Therefore, the *AF* portion of this floor is supported by outside wall *AC*. In like manner, partition *KN* and column *NQ* support the second and first floors between points *JL* and *MO*. Thus, portions *BJ* and *CM* of the second and first floors are also supported by outside wall *AC*. The portions of floor supported by the opposite outside wall are determined in the same manner.
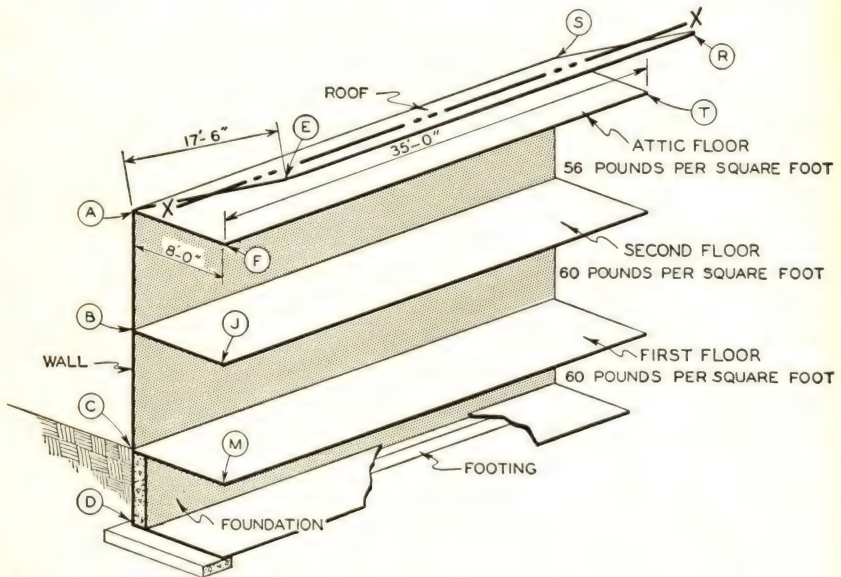
Fig. 2. Parts of the Roof, Floors, and Outside Walls Are Supported by the Foundation

Suppose that the residence shown in the pictorial view in Fig. 1 could be cut or sawed into two parts, making the cut along line *X–X* vertically so that it passed through points *F*, *J*, *M*, and *P*. Suppose that the larger portion of the residence is moved away so that the remaining part is as shown in Fig. 2. Outside wall *AC* in Fig. 2 is the same as outside wall *AC* in Fig. 1. Portions of floor *AF*, *BJ*, and *CM* in Fig. 2 are the same portions of floor indicated by the same letters in Fig. 1. Thus, Fig. 2 shows those portions of the roof and floors which are supported by one of the outside walls. The opposite outside wall supports like portions of the roof and floors. It can easily be seen that only two outside walls are necessary in most cases to

support the roof and floors of a building. The other portions of the floors in Fig. 1 are supported by interior partitions *GK* and *KN* and by column *NQ*.

From the foregoing descriptions it can readily be seen that foundation *CD* in Figs. 1 and 2 must support all of the weight, not only from the roof and portions of the floor, but from outside wall *AC* as well. This combined or total weight is considerable as will be shown in the following analysis.

That part of the roof supported by the outside wall *AC* in Fig. 2 is shown by the letters *AESR*. This is just half of the roof and the dimensions are 17′ 6″ x 35′ 0″. The area of this portion of the roof is 17.5 × 35 or approximately 613 square feet. The portion of the attic floor supported by this same outside wall is shown by the letters *AFST*, the dimensions for which are 8′ 0″ x 35′ 0″. This gives an area of 280 square feet. The portions of the second and first floors supported by the outside walls have exactly the same areas.

Roofs and floors are assumed to have a certain weight due to the structural materials of which they are built. This weight is called the *dead load*. They are also assumed to have a certain weight due to people, furnishings, and other movable objects. This is known as the *live load*. Both loads are spoken of in terms of so many pounds per square foot. Both live and dead loads must be taken into consideration when planning any structure. Table I shows such loads.

TABLE I. LOADS FOR AVERAGE RESIDENCES*

STRUCTURAL ITEM	COMBINED LIVE AND DEAD LOADS (POUNDS PER SQUARE FOOT)	LIVE LOADS ONLY (POUNDS PER SQUARE FOOT)
Roofs—Pitched..........	35	25
Roofs—Flat.............	40	30
Attic Floor..............	56	40
Second Floor	60	40
First Floor	60	40
2x4 Partitions......	12	....

*These loads vary greatly in building codes of various cities. The loads given here are typical.

It can be seen from Table I that the combined load for a pitched roof such as shown in Figs. 1 and 2 is 35 pounds per square foot. Therefore, the total load for that part of the roof supported by outside wall

AC is equal to the area multiplied by the load per square foot. In this case it would be 613 × 35, or 21,455 pounds. Table I also shows that the combined live and dead load for an attic floor is 56 pounds per square foot. The total load from that part of the attic floor supported by outside wall *AC* is therefore 280 × 56, or 15,680 pounds. In like manner, the total load from the second floor is 280 × 60, or 16,800 pounds. The total first floor load is also 16,800 pounds. If it is assumed that the outside walls are built of brick and are 8″ in thickness, then each square foot of wall area, according to Table II, weighs

TABLE II. WEIGHTS OF MATERIALS

MATERIAL	WEIGHT IN POUNDS PER CUBIC FOOT	WEIGHT IN POUNDS PER INCH THICKNESS
Brick Masonry	125	10.5
Concrete	150	12.5
Cinder Blocks	....	6
Concrete Blocks	....	8
Rubble Stone	....	12.5
Clay Tile.................	....	4.5

10.4 × 8, or approximately 83 pounds. The wall dimensions are 20′ 0″ x 35′ 0″, which makes an area of 700 square feet. At a weight of 83 pounds per square foot, the wall will constitute a load on the foundation of 700 × 83, or 58,100 pounds.

The total load in pounds, including the roof, floors, and walls, is:

Roof	21,455
Attic Floor	15,680
Second Floor	16,800
First Floor	16,800
Wall	58,100
Total load	128,835

The foundation along a length of 35′ 0″ supports a load, therefore, of 128,835 pounds. For each lineal foot of the foundation the load is 128,835 ÷ 35, or 3,681 pounds. The foundation must be strong and firm to support such a load without allowing settlement, uneven floors, plaster cracks, and many other annoying and even dangerous possibilities.

Table III shows live and dead loads which must be considered in the design of foundations for farm buildings. The weight per cubic foot of produce in this table should be especially noted.

TABLE III. DEAD AND LIVE LOADS

DEAD LOADS	POUNDS PER SQUARE FOOT
Roofs*	
Ordinary gable roofs (including sheathing, wood shingles)†	6
Braced rafter barn roof (includes slats, wood shingles)†	13
Gothic, sawed rafters (includes sheathing, wood shingles)†	12
Asbestos shingles (additional weight)	3
Built-up tar and gravel roofing (additional weight)	4.5
Slate, ⅛″ to ¼″ thick (additional weight)	4.5 to 6.5
Framing	
Lumber in general (per foot board measure)‡	2.5
2 x 12 joists, spaced 2′ 0″ apart	2.6
2 x 10 joists, spaced 16″ apart	3.1
2 x 8 joists, spaced 2′ 0″ apart	1.7
Sheathing, flooring, or drop siding	2.5
Plaster on wood lath	6 to 8
Plaster on metal lath	10
2 x 4 studs, spaced 16″ apart (includes plates and sills)	2
2 x 4 studs, spaced 2′ 0″ apart (includes plates and sills)	1.5
2 x 6 studs, spaced 2′ 0″ apart (includes plates and sills)	2.3
Cement stucco	10
Stud partition, plaster on both sides	16
Masonry	
Cinder block wall, pounds per inch of thickness	6
Concrete block wall, pounds per inch of thickness	8
Brick wall, pounds per inch of thickness	10.5
Rubblework or solid concrete wall, pounds per inch of thickness	12.5
Clay tile wall, pounds per inch of thickness	4.5

LIVE LOADS	
First floor in dwellings	40
Second floor in dwellings	30
Attic floor in dwellings	20
Roofs in general	20 to 40
Assembly halls (where crowds collect)	100

Weight of Produce	POUNDS PER CUBIC FOOT
Apples, carrots	40
Beans, beets, potatoes, wheat, shelled corn**	48
Ear corn, husked††	28
Oats**	26
Bran	16
Loose hay	4 to 5
Chopped hay	10 to 13
Ordinary baled hay	10 to 13
Baled straw	6
Lime, fertilizer	55 to 60

*Pounds per square foot horizontal projected roof area.
†Two pounds included for wood shingles; roll roofing, tin, and corrugated metal about same weight.
‡One board foot (1 foot B.M.) of lumber is equal to 1 square foot 1 inch thick. For estimating the weight of lumber of various dimensions, calculate the feet B.M. (multiply the width by the thickness in inches and by length in feet and divide by 12).
**Small grains occupy about 1¼ cubic feet per bushel.
††Ear corn, cleanly husked, occupies about 2½ cubic feet per bushel.

Foundations Guard against Frost Action. It is a well-known fact that when water freezes its volume increases. The same situation exists when moist soil freezes. In the case of soil, the increase in volume causes an upward movement which is called heaving. This heaving causes any structure to move upward with the expanding soil unless the foundations for such structures extend below the lowest freezing point in the soil. When the soil thaws, it settles to its original volume. A house or barn would settle with the soil if the foundations did not extend below the point at which the settlement takes place. Therefore, foundations are used to prevent any possible upward or downward movement. Such movement causes plaster cracks and other annoyances and might even endanger a building.

Foundations Provide Basements. The only way in which basements can be provided below grade is through the use of foundations which cannot be harmed by moist earth. The foundations also prevent the sides of the basement from caving in. In the section view of Fig. 1, two arrows are shown which indicate the direction of the soil pressure on the sides of the foundation walls. The foundations resist this pressure and also serve as a means of keeping basements dry.

Foundations Protect against Termites. In many parts of the United States, antlike insects called termites attack and eat any wood which comes in contact with the soil in which they are found. Foundations and termite shields raise and isolate all wood parts of a structure above the soil, thus guarding it from attack by the tiny insects.

KINDS OF FOUNDATIONS

There are as many kinds of foundations as there are kinds of buildings. Some of them are good while others are poor. Some of them serve the purpose for which they were intended while others fail. Perhaps the most common reason for failure of foundations is the desire in builders to save on structural costs. Such economy is false and a bad investment. Good foundations are expensive but their cost is one of the best investments in any structure. In the following general explanations, only those types of foundations which are recommended by engineers and building codes are considered.

Concrete Foundations. Fig. 3 shows a typical concrete foundation

for an average residence. This foundation has the advantage of being integral or all in one piece. All parts of it were poured at the same time with the result that when it hardened, it became one solid piece of concrete. This prevents any part of the foundation from settling away from the rest. Thus, it insures a firm and continuous support for the residence.

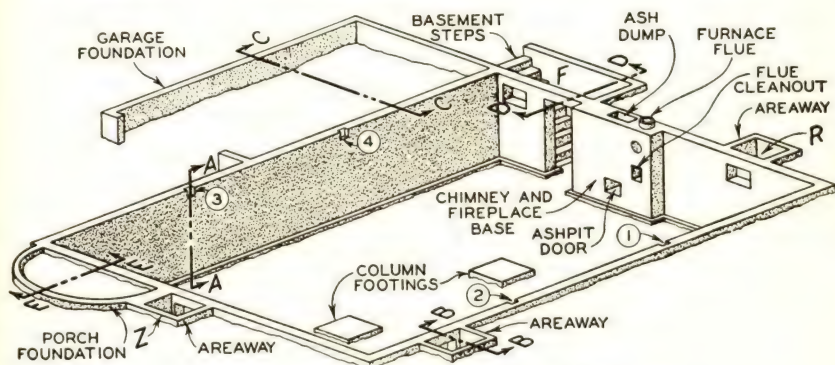In Fig. 3 the portion of the illustration at *A–A* shows the foundation which extends from the ground level down to the footings which

Fig. 3. Foundation of Concrete for Small Residence

are below the basement floor level. The foundation at *C–C* is for the garage. The circular foundation at *E–E* is for a front entrance porch. At *B–B* is shown an areaway which is necessary for basement windows which are below ground level. Areaways are shown also at *Z* and *R*. The foundation at *F* is a retaining wall around exterior stairs. At the middle of the rear portion of the foundation is the fireplace and chimney foundation. Note the cleanout doors. Note the recesses or pockets in the foundation at points marked *1*, *2*, *3*, and *4*. These recesses serve as bearing surfaces for the two beams which will be used to support the interior sections of the house in the same manner as the beam shown in the section view of Fig. 1. The various foundation refinements mentioned in connection with Fig. 3 will be more fully explained and illustrated in succeeding pages.

The illustration in Fig. 4 shows the main foundation and footing in section as they appear at *A–A*. Note that the recess or pocket for the beam bearing surface is visible. If this figure is visualized in connection

with Fig. 3, the main foundation will then be easier to understand.

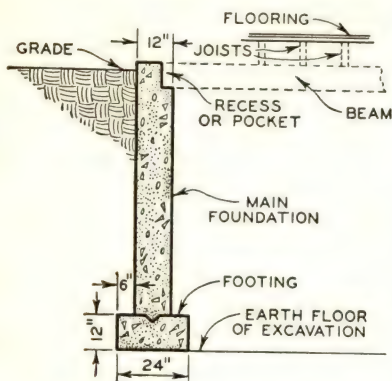This type of concrete foundation is the one most generally used. Its thickness and the thickness of the footing depends upon the load it must support and upon its height. The channel in the top of the footing locks the foundation to the footing, thus preventing the sideward displacement of the foundation by earth pressure. The channel also serves to help prevent moisture from seeping through into the basement.

Fig. 4. Section at A–A of Main Foundation Shown in Fig. 3

The section view in Fig. 5 shows a concrete foundation similar to the one in Fig. 4 except that the first floor level in Fig. 5 is considerably above grade. This necessitates a much shorter foundation. Note that in a case of this kind the wall of the structure rather than the foundation is depended upon to support the beam ends. In all cases where first floor levels are above the grade line and where full-height basements are required, the concrete foundation is built only up to the grade line.

The section view in Fig. 6 gives the details of the garage foundation which was shown at C–C in Fig. 3. Note that no footings are required and that the foundation extends only to a depth below frost line. Note, too, that this foundation need not be as thick as the main foundation because the garage is light when contrasted with the residence.

Fig. 5. Section of Foundation Wall Where Grade Is Below First Floor

The section view in Fig. 7 shows the details of the porch foundation which was designed as E–E in Fig. 3. This foundation, like the one for the garage, is only 8″ thick. It requires no footing and extends down only to a point below the frost line.

Details of the areaway walls are shown in Fig. 8. Note that only 6″ walls are required and that the frost depth need not be considered. The areaway walls do not support any part of the structure and since they are an integral part of the foundation, could not easily be pushed
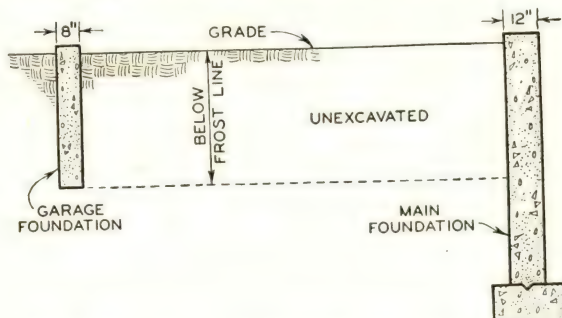

Fig. 6. Section at C–C of Garage Foundation Shown in Fig. 3

upward due to the heaving of the ground. Note, too, that the better areaways will have a concrete floor slightly below the sill of the window as well as a drain and sloping floor for rain water and melting snow.
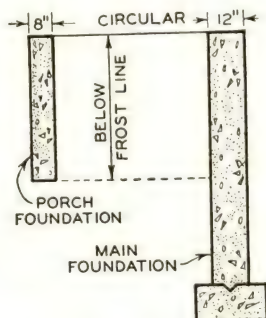
Fig. 7. Section at E–E of Porch and Main Foundation Shown in Fig. 3
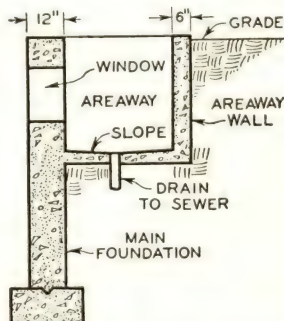
Fig. 8. Section at B–B of Areaway Wall in Foundation Shown in Fig. 3

Fig. 9 shows both plan and section views of the exterior stairway of Fig. 3. The section view of Fig. 9 is taken along the line *F–F* in the plan view. Note that the stair or retaining wall is only 8″ thick but that because of its height and weight, a footing is advisable. The

stair wall and the steps are poured at the same time so that they are all of one piece. This prevents any possible displacement of the steps due to frost action.

Concrete foundations for barns are similar to those just described for residences except that barns do not have basements. Because of this, barn foundations such as shown in Fig. 10 need extend down only
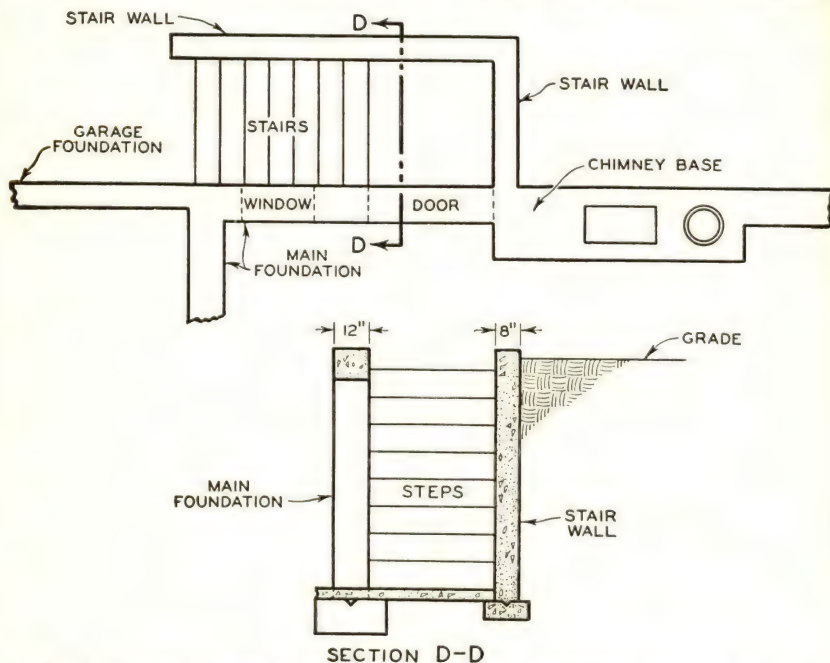

SECTION D–D

Fig. 9. Plan and Section Views of Stair Wall at *F* in Foundation Shown in Fig. 3

far enough to be below the frost line. The foundations for other farm buildings are similar and vary in thickness only according to loads.

CONCRETE PILASTERS. Pilasters, shown in Fig. 11, are used to stiffen long foundations and also to serve as increased bearing surface for the ends of beams. Stiffening of concrete foundations is seldom necessary except in cases where they are very high and over 20′ 0″ long in any direction. For the ordinary residence, barn, store building, or other small structure, there is seldom any need for pilasters. Exceptionally high foundations are subject to considerable soil pressures and pilasters act as braces in helping to resist this pressure.
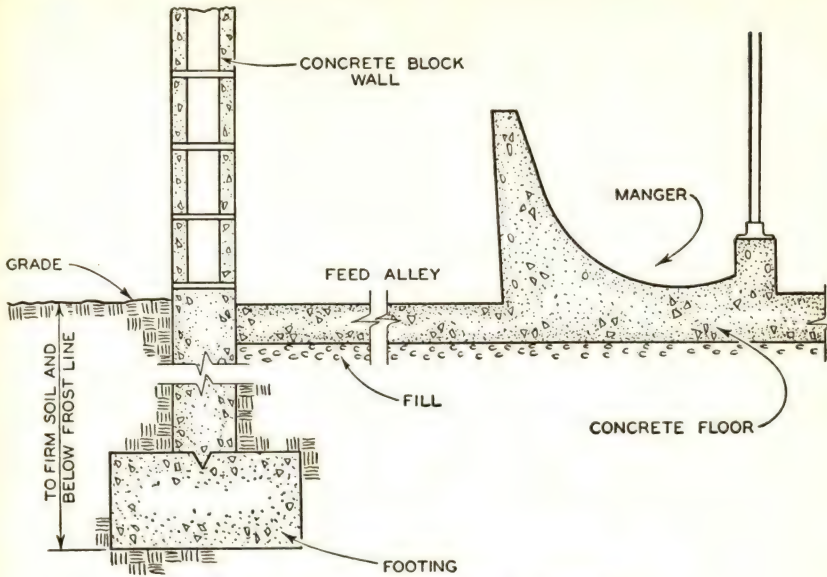
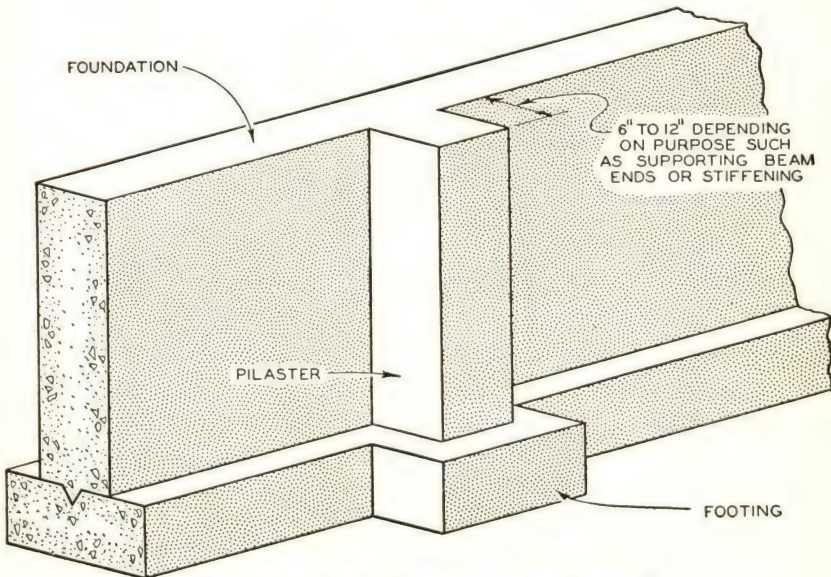Fig. 10. Concrete Foundation for Dairy Barn

Fig. 11. Concrete Foundation with Integral Pilaster

Generally speaking, concrete foundations are of sufficient thickness and strength to provide safe bearing surfaces for beams as was shown at points *1, 2, 3,* and *4* in Fig. 3 and in Figs. 4 and 5. However, it sometimes happens that a beam supporting an exceptionally heavy load imposes too great a burden on the foundation. In such cases a pilaster is necessary.
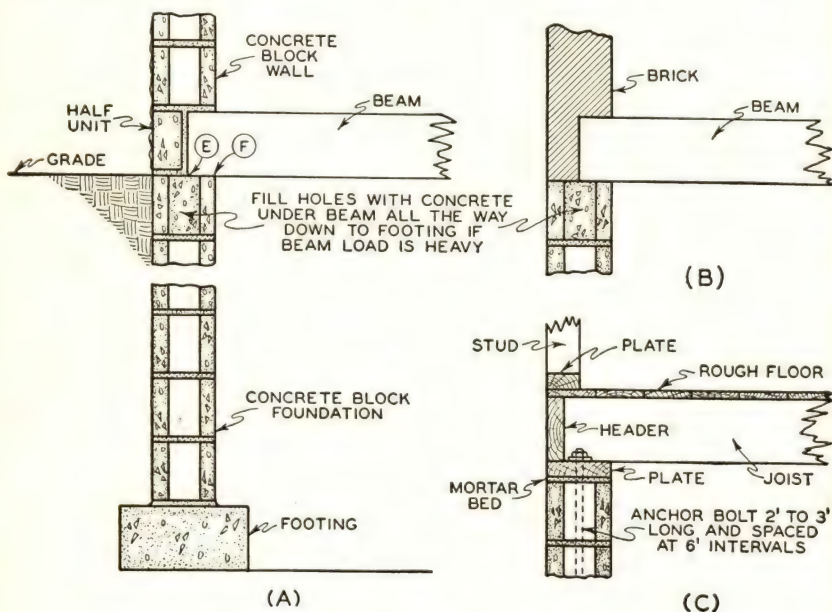

Fig. 12. Section of Concrete Block Foundation

Instead of specifying a concrete pilaster, some architects use bricks to build the structure. Such pilasters usually consist of one or more thicknesses of brick courses laid directly against the foundation from the footing to the under surface of the beam. A complete discussion of pilasters is given in the chapter on Columns.

Concrete Block Foundations. The use of concrete blocks for foundations under small residences, barns, and other such buildings is usually preferred when cast-in-place concrete is not used. As the second most common material used for building such foundations, concrete blocks are rapidly laid and, if the mason is careful, make good foundations.

A typical concrete block foundation is shown in (A) of Fig. 12.

Blocks used for building foundations should be made of good concrete (not cinder) and should be carefully cured for at least two weeks before being used. The concrete in such blocks should be well packed. Dimensions for all blocks should be exactly the same and no blocks with broken edges or corners should be used.

At points where such foundations support the ends of beams which are to be heavily loaded, the blocks underneath and on either side of
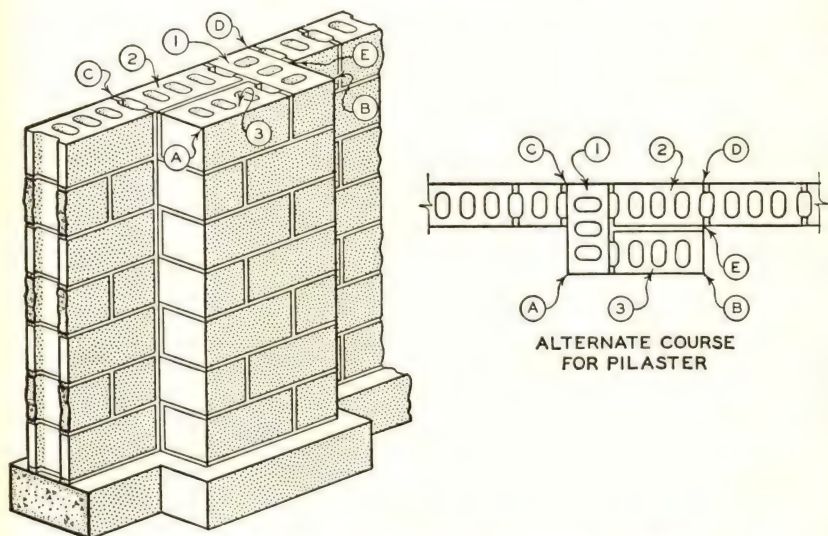

ALTERNATE COURSE
FOR PILASTER

Fig. 13. Section of Concrete Block Foundation and Pilaster

the beam from the footing to the beam bearing surface should have their cores filled with a 1:2:4 concrete. This practice gives the foundation much the same strength as could be expected from a poured-in-place foundation.

When concrete block walls are to be built above the foundation as in (A) of Fig. 12, half units can be used at beam bearing points to provide ample bearing surface, as shown by letters *EF*. When brick walls are specified, the bricks are simply laid around the beam end as shown in (B). If frame (wood) walls are to be used, the plate on which the beam rests should be anchored to the foundation as shown in C. Anchor bolts should extend down from 2′ to 3′ in the block foundation and should be spaced at about 6′ intervals.

Concrete block foundations such as shown in Fig. 12 are especially applicable to all farm structures for which outside walls of masonry materials are planned.

CONCRETE BLOCK PILASTERS.   In concrete block foundations, pilasters are employed for the same purposes explained for concrete foundations. However, in concrete block walls, pilasters are necessary as
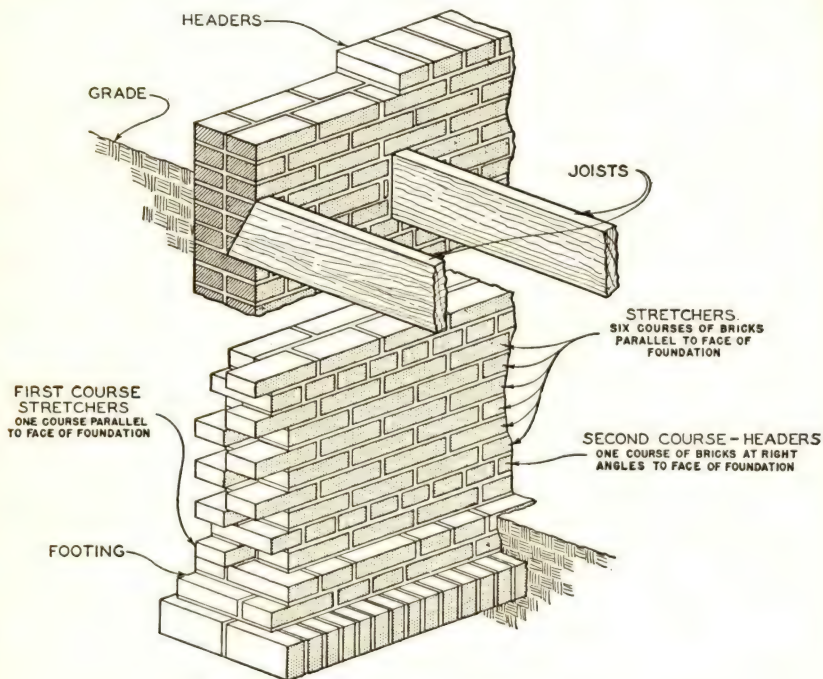
HEADERS

GRADE

JOISTS

STRETCHERS.
SIX COURSES OF BRICKS
PARALLEL TO FACE OF
FOUNDATION

FIRST COURSE
STRETCHERS
ONE COURSE PARALLEL
TO FACE OF FOUNDATION

SECOND COURSE - HEADERS
ONE COURSE OF BRICKS AT RIGHT
ANGLES TO FACE OF FOUNDATION

FOOTING

Fig. 14. Section of Brick Foundation and Footing

stiffening agents even in ordinary height foundations when they are over 30′ in length. Also, where heavily loaded beams have their bearing in such foundations, rather large pilasters (see Fig. 13) are required.

Brick Foundations.   After a study of Fig. 14, it can be seen that a brick foundation is not greatly different from a concrete or concrete block foundation. In order to withstand the dampness and chemical properties of the soil, brick foundations should be built of hard-burned bricks and Portland cement mortar.

A well-built brick foundation compares favorably with foundations

made of other materials in strength, dependability, and time consumed during construction. The fact that poured-in-place concrete foundations are more common simply means that they can be built using a smaller percentage of skilled labor than is possible when laying up a good brick foundation.

BRICK PILASTERS. Brick pilasters serve the same purposes as pilasters made of other materials.
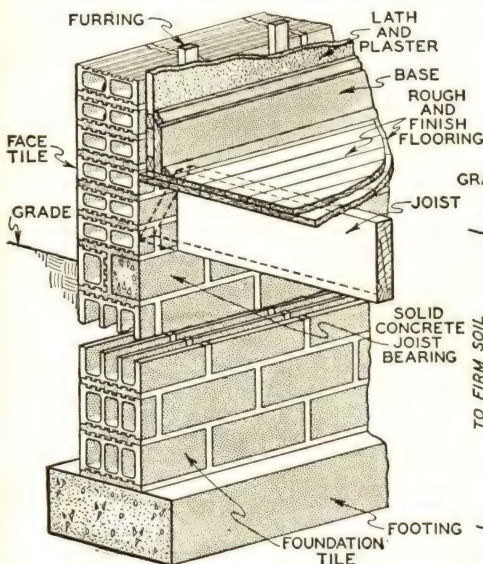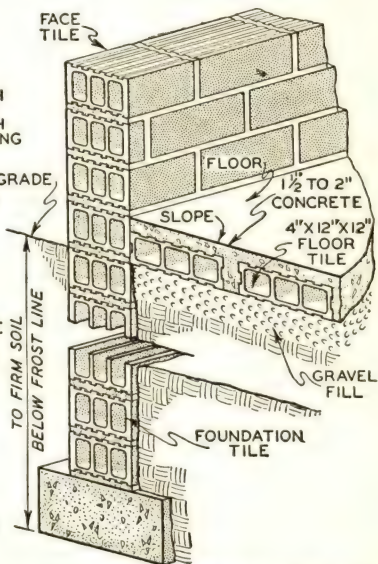

Fig. 15. Tile Foundation for Residence   Fig. 16. Tile Foundation for Dairy Barn

Tile Foundations. Tile used for foundations such as shown in Fig. 15 should conform to the requirements for grade LBX tile as set forth in the specifications for load-bearing wall tile prepared by the American Society for Testing Materials.[1] Tile of this specification can safely withstand frost, moisture, and other soil conditions for which other classes of tile are not designed and manufactured. When correct tile and proper mortar are used, tile foundations serve the purpose as well as foundations built of other materials.

Tile having thicknesses of 5″, 8″, 10″, or 12″ with lengths of 12″ or 16″ are generally used for foundations. The use of such tile having a

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[1]Copies of these specifications can be secured from the American Society for Testing Materials, Philadelphia, Pa.

depth of 5″ or more is illustrated in Fig. 15. Mortar for use with tile foundations can be a mix of one part Portland cement to three parts sand or a like mix with 0 to ¼ parts of hydrated lime or lime putty added to it.

Tile foundations are used extensively in connection with tile farm structures as shown in Figs. 16 and 17. Such foundations need be
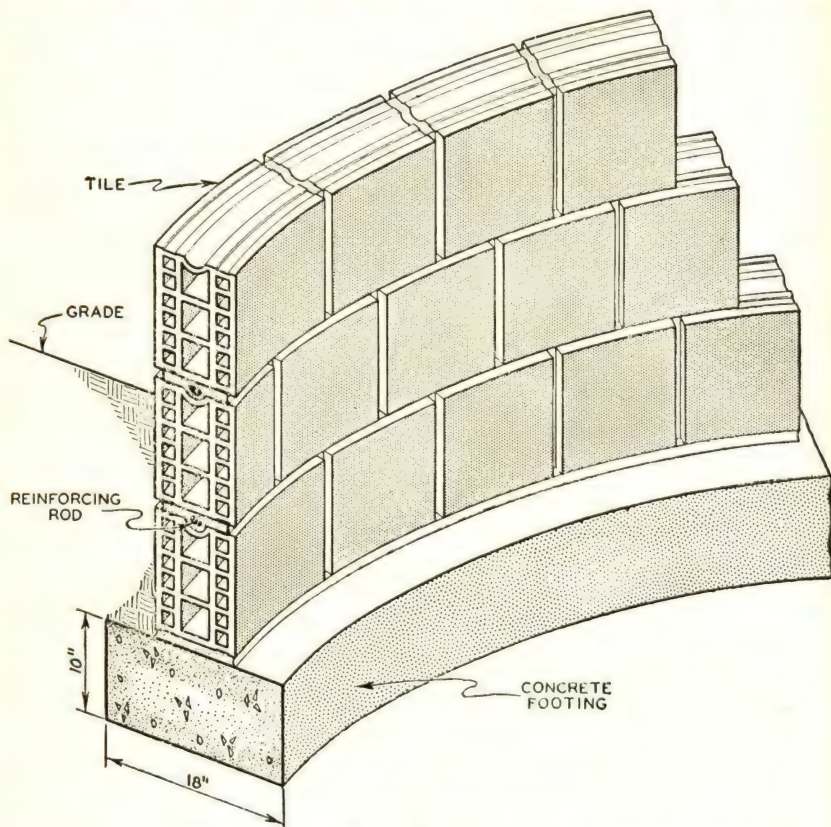

Fig. 17. Tile Foundation for a Silo

only deep enough to insure their being below the greatest frost penetration encountered in that particular area.

TILE PILASTERS.   Pilasters erected in conjunction with tile foundations serve the same purposes explained for pilasters built of other materials. A tile pilaster can be made much stronger by filling in the open areas with 1:2:4 concrete.
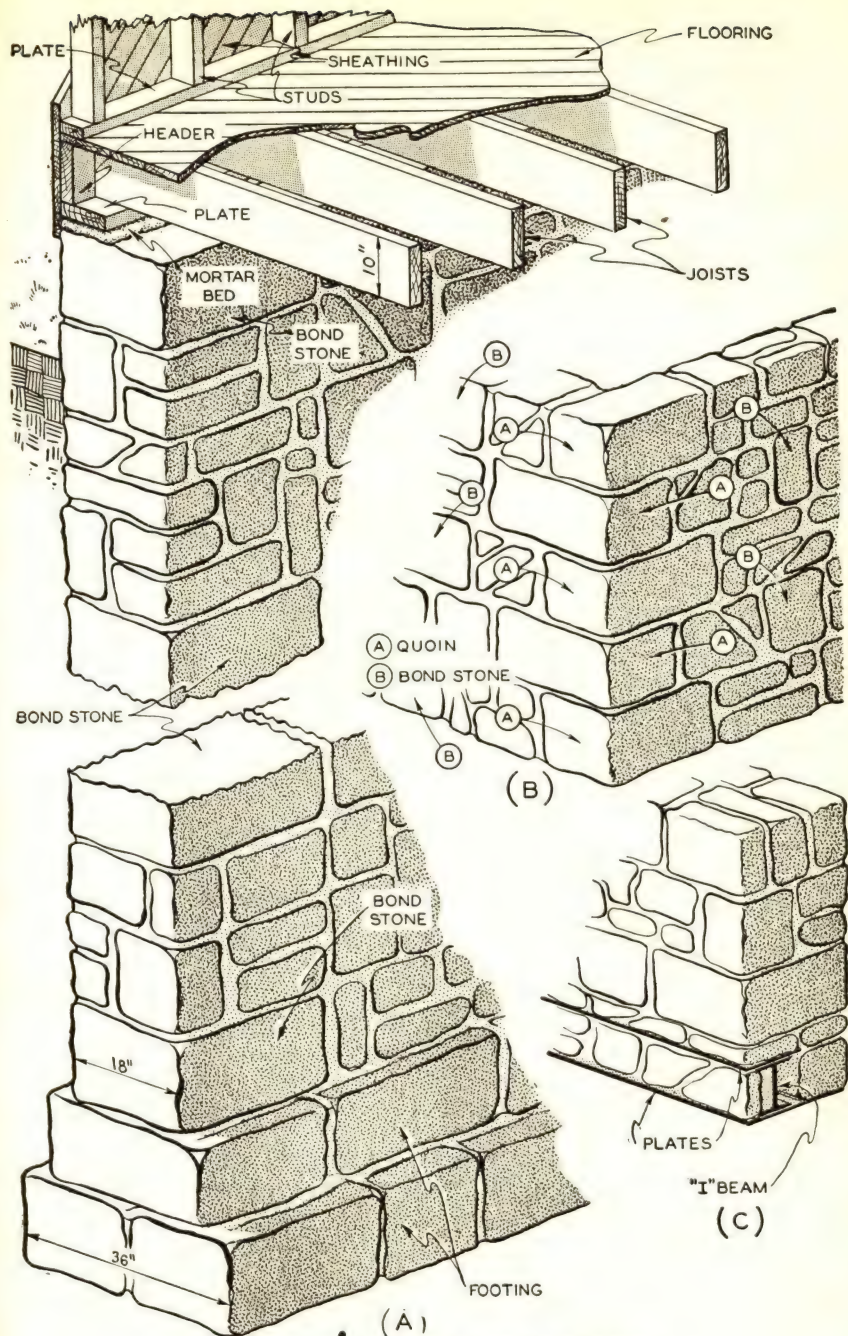
PLATE
FLOORING
SHEATHING
STUDS
HEADER
PLATE
MORTAR BED
BOND STONE
10"
JOISTS
BOND STONE

(B)
(A) QUOIN
(B) BOND STONE

BOND STONE

18"
36"
FOOTING
BOND STONE
(A)

PLATES
"I" BEAM
(C)

Fig. 18. Detail of a Typical Stone Foundation

Stone Foundations.   There are few building materials more pleasing in effect and which lend themselves to a greater variation of expression than stone. Rubble is the term usually applied to such stonework as is commonly used for foundations. This construction requires but little tool work on the stones other than to break them with the hammer and roughly dress (shape) them as shown in (A) of Fig. 18.
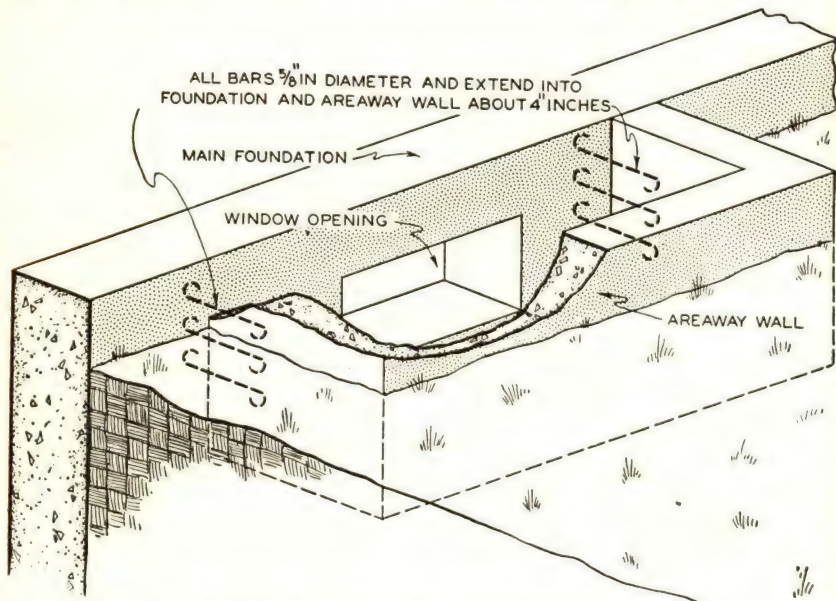
ALL BARS ⅜" IN DIAMETER AND EXTEND INTO
FOUNDATION AND AREAWAY WALL ABOUT 4" INCHES

MAIN FOUNDATION

WINDOW OPENING

AREAWAY WALL

Fig. 19. Use of Reinforcing Rods to Tie Areaway Wall to Main Foundation

In many sections of the country there are deposits of stratified rock such as limestone from which pieces can be obtained easily through the use of hammers and wedges. Boulders and field stones are often found in streams and fields, respectively. Any such stone makes suitable material for rubble stone foundations.

From Fig. 18 it will be noted that the bearing edges of stones for good foundation construction should be nearly flat. This makes for thinner and therefore stronger joints and, in addition, requires the use of much less mortar. The use of cobblestones (small, nearly round stones) should be confined to veneers or facings for walls made of other types of masonry such as brick or concrete blocks.

Mortar for stone foundations should be made of a mix consisting

of one part Portland cement and not more than three parts of clean sand.

STONE PILASTERS. Pilasters in stone foundations serve the same purposes described for pilasters used with foundations built of other materials.

DESIGN OF FOUNDATIONS

Most cities throughout the United States publish building codes setting forth definite and rigid specifications regarding, among other things, the design of foundations for various types of buildings. Since these codes are the law, architects and masons must follow them to the letter. This means that in localities where such codes exist, foundations need not be designed. Instead, the architect merely indicates them on the plans as being built in accordance with existing regulations.

Generally speaking, building codes give exact thickness dimensions as well as allowable heights for foundations. The materials which may be used in building foundations are listed along with limitations on outside wall thicknesses and the number of floors. For example, the building code published by Highland Park, Illinois, states that for two story brick residences the foundation must be 12″ thick if built of regular, plain concrete.

With this in mind, it is always a good policy for a mason to ascertain if there is a building code in any city or town in which he anticipates building foundations. Should such a code exist, he must carefully follow all specifications as to thicknesses and heights for his foundations.

In small towns and rural areas, building codes are not common. As a result, foundations must be designed for each building. If plans prepared by architects are not available, the mason must do the required designing.

Concrete Foundations. Concrete foundations for residences, barns, apartment buildings, and other small structures can be designed satisfactorily, specifications being based on the thicknesses of outside walls above the foundation and on the number of floors in the buildings. The following general rules will apply to most small buildings:

1. ONE STORY RESIDENCES
   a) *Wood frame without basement.* Make foundations at least 6″ thick.
   b) *Wood frame with basement.* Make foundations at least 8″ thick, or at least 10″ thick if they are longer than 20 feet.

    c) *Masonry exterior walls.* Make foundations at least as thick as the walls they support.

    d) *Brick or stone veneer with wood frame.* Make walls 8″ thick if veneer does not extend more than 1¼″ beyond the edges of the foundations. Otherwise, increase thickness of foundation to the extent that veneer does not extend more than 1¼″ beyond the edge of the foundation.

2. TWO STORY RESIDENCES WITH BASEMENTS
    a) *Wood frame.* Make foundations 10″ thick if they do not extend more than 7′ 0″ below grade line. Make them 12″ thick if they extend below 7′ 0 inches.

    b) *Masonry walls.* Make foundations at least the same thickness as the wall they support if the foundation does not extend more than 7′ 0″ below grade. If the foundation extends more than 7′ 0″, make it at least 12″ thick.

    c) *Brick or stone veneer with wood frame.* Make foundations at least 10″ thick if they do not extend more than 7′ 0″ below grade and at least 12″ in thickness if they go below that depth.

3. TWO AND THREE STORY APARTMENT BUILDINGS WITH BASEMENTS
    a) *Wood frame. See* 2c).

    b) *Masonry walls.* Make foundations at least as thick as the walls they support for a two story building and at least 12″ thick for a three story building.

4. ONE STORY STORE BUILDING
    a) *Wood frame without basement.* Make foundations at least 8″ thick, or at least 10″ thick if they are longer than 25 feet.

    b) *Wood frame with basement.* Make foundations at least 10″ thick, or at least 12″ thick if they are longer than 25 feet.

5. TWO AND THREE STORY STORE BUILDINGS WITH BASEMENTS
    a) *Masonry walls. See* 3b).

6. ONE STORY DAIRY BARNS
    a) *Wood frame.* Make foundations at least 8″ thick if they are not over 25′ in length and at least 10″ thick if they are longer than 25 feet.

    b) *Masonry side walls.* Make foundations at least as thick as the walls they support and at least 12″ thick if they are longer than 25 feet.

7. DAIRY BARNS WITH HAYMOWS
    a) *Wood frame.* Make foundations at least 10″ thick if they are not over 25′ in length and at least 12″ thick if they are longer than 25 feet.

    b) *Masonry walls.* Make foundations at least as thick as the masonry walls they support and at least 12″ thick if they are longer than 25 feet.

8. ONE STORY RESIDENCE GARAGES WITHOUT BASEMENTS (see Fig. 6)
    a) *Wood frame.* Make foundations at least 8″ thick.

    b) *Masonry walls.* Make foundations at least as thick as the walls they support but not less than 8 inches.

9. MISCELLANEOUS SMALL FARM STRUCTURES
    a) *Wood frame.* Make foundations at least 8″ thick, or at least 10″ thick if they are over 25′ in length.
    b) *Masonry Walls.* Make foundations the same thickness as the walls they support but not less than 8″ and 10″ if they are longer than 25 feet.
10. RESIDENCE PORCH FOUNDATIONS (See Fig. 7). Make foundations 6″ or 8″ thick.
11. RESIDENCE AREAWAY WALLS (see Fig. 8). Make walls at least 6″ thick.
12. RESIDENCE EXTERIOR STAIR WALLS (see Fig 9). Make walls at least 8″ thick.

CONCRETE PILASTERS. When a concrete pilaster is used to create added support for a beam end, its size generally depends on the thickness of the foundation of which it is a part. In small buildings such as residences, barns, and stores, a pilaster having a width and thickness one-half that of the foundation will serve the purpose satisfactorily. In most cases it will be larger than necessary but the added size makes for a comfortable margin of safety.

When pilasters are used to stiffen exceptionally long foundations, their width and thickness should be at least equal to the thickness of the foundation. The stiffening of foundations with pilasters is a safeguard against their tendency to lean or fall. There is some danger of this happening, especially in long, straight foundations such as are found in store buildings. If such foundations are longer than 50′, pilasters should be employed at 25′ intervals. It is recommended that a structural engineer be consulted with regard to foundations which are longer than 75 feet.

A structural engineer should be consulted also in connection with the building of grain elevator, warehouse, and office building foundations if architect-prepared plans are not available.

Concrete Block Foundations. There are no rules commonly agreed upon, such as were set forth for concrete foundations, in connection with foundations built of concrete blocks. However, the strengths of such foundations can be easily calculated and the load limitations established for most purposes.

The compressive strength of good concrete blocks[2] can be safely

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[2]See "American Standard Building Code Requirements for Masonry" published by the Bureau of Standards of the U.S. Department of Commerce at Washington. D.C.

assumed to be 80 pounds per square inch gross area if the blocks are laid in Portland cement mortar. In other words, if an 8″ x 12″ concrete block has a gross area of 96 square inches (8 × 12 = 96, including holes), it can safely support a load of 96 × 80, or 7,680 pounds. If a foundation is built of 8″ x 12″ concrete blocks, it can support 7,680 pounds per lineal foot, provided Portland cement mortar is used in the construction.

In the section in this chapter on the theory of foundations, the weight on each lineal foot of foundation for a typical residence was calculated as 3,681 pounds. Thus, an 8″ concrete block foundation is over twice as strong as is necessary.

The weight per lineal foot of foundation can be calculated for any small building by following the same procedures described for the residence in the first section of this chapter. Then the strength of any size concrete block foundation can be determined to see if it will be strong enough to do the job.

CONCRETE BLOCK PILASTERS. The strength of concrete block pilasters is calculated in exactly the same manner as explained for concrete block foundations. Determine the gross area in square inches of the pilaster, including the foundation (or area *ABCD* in Fig. 13), and multiply the result by 80 if Portland cement mortar is used. By comparing the strength of the pilaster with the beam-end load it is to carry, the proper size of the pilaster can be checked. Pilasters can be made larger or smaller to suit load demands. The strength of such pilasters can be appreciably increased by filling the holes with a mixture of 1:2:4 concrete.

Concrete block pilasters are also used in concrete block foundations as stiffeners at 30′ intervals where the foundation is exceptionally long. The pilaster shown in Fig. 13 is considered of adequate size to act as a stiffening agent.

Brick Foundations. There are no generally accepted rules relative to the design of brick foundations as there are for foundations built of concrete. However, the strengths of brick foundations can be calculated by assuming that brickwork, when laid up with Portland cement mortar, has a compressive strength of 200 pounds per square inch. For example, if a brick wall is 8″ wide, its area per lineal foot is 8″ × 12″, or 96 square inches. The strength of such a wall per

lineal foot will be 96 × 200, or 19,200 pounds. It is obvious that this figure is many times the strength required to support the load calculated for the small residence discussed in the first pages of this chapter. Because of the great compressive strength of brick, foundations built of them are much stronger than necessary in the majority of cases.

Brick foundations must always be at least as thick as the walls they support and thicker if the load requirements so indicate. A typical brick footing and foundation are shown in Fig. 14.

BRICK PILASTERS. Strengths for brick pilasters are determined in the same manner as was described for brick foundations. If a pilaster in an 8″ foundation is 12″ thick and 12″ wide, including the foundation, its area is 12″ × 12″ or 144 square inches. This, multiplied by 200, gives 28,800 pounds as the load which the pilaster could be expected to support. Brick pilasters also are made larger or smaller according to the load requirements expected of them.

When brick pilasters are used as stiffeners, they are spaced a maximum of 30′ apart in long foundations. They are seldom necessary in ordinary small buildings.

Tile Foundations. The design and construction of tile foundations is similar to that described for concrete, concrete block, and brick foundations with the exception that the compressive strength of clay tile is 80 pounds per square inch when the tile is laid up in a Portland cement mortar. Tile foundations should be at least as thick as the walls they support, as shown in Figs. 15 and 16. A typical tile silo foundation is shown in Fig. 17.

TILE PILASTERS. Tile pilasters are designed and erected using the same procedures described for concrete blocks. Like concrete block pilasters, those made of clay tile may have their strengths materially increased by filling the inside of each tile with a mixture of 1:2:4 concrete.

Stone Foundations. Foundations built of stone for residences or farm buildings must be at least 16″ to 18″ thick. There are no standard compressive strengths for random stone nor any rules except that long experience has shown that a 16″ to 18″ foundation will safely support a two story frame or masonry residence or barn providing the foundation is laid up with Portlant cement mortar. Much of the strength of such a foundation is dependent upon the care exercised

during its construction. A typical stone foundation is shown in Fig. 18.

STONE PILASTERS. Where stone pilasters are required, they should be (including the foundation) at least 1½ times the thickness of the foundation.

BUILDING OF FOUNDATIONS

The methods of laying out foundation excavations by the use of batter boards as well as the construction of footings have been thoroughly discussed in the two previous chapters. The following descriptions concerning foundation construction are based on the assumption that the excavations have been properly made and the footings in and ready for the foundation to be built on them.

Concrete Foundations. For ordinary foundation conditions, a concrete mix of 1:2¾:4 is recommended. The aggregate should not be larger than 1½″ and not more than 6¼ gallons of water per sack of cement should be used when the sand is damp, or not more than 5½ gallons if the sand is very wet. If the first batch is too stiff or too wet, reduce or increase the amount of sand or gravel but do not change the water ratio. When foundations are to be built in wet soil, a 1:2¾:3 mix is recommended.

The formwork for main foundations, porch and garage foundations, areaway walls, exterior stair walls, window and door openings, and exterior steps as illustrated in Fig. 3, was described in detail in Chapter I.

Before the main foundations are poured, it is important to make provisions for the beam-end bearing pockets as were shown in Fig. 3. Forms for these should be used which are easily removable without damage to the finished concrete.

Areaway walls, porch and garage foundations, and walls for exterior steps should either be poured at the same time as the main foundation or should be securely tied to it by the use of reinforcing bars. Pouring of the entire foundation as an integral mass in one operation is the most desirable condition. There is, then, no chance that areaways, walls, and other parts will separate from the main foundation. This requires much more labor in building the forms but is worth while. If rods are used to tie areaway walls to the main foundation, they should be arranged similar to those shown in Fig. 19.

The rods are set into the main foundation forms before the concrete is poured. At a later date when the areaway forms are set up, the ends of the rods protrude into the areaway forms and are embedded in the concrete when it is poured.

When all the forms are ready, the concrete is mixed and poured. It is usually deposited in the forms in layers of from 6″ to 12″ in thickness, starting at one corner of the foundation and gradually working away from that corner in two directions. An effort should be made to pour the various layers so that the entire foundation builds up gradually. It is not good practice to fill the forms on one side before the forms on the other side are half filled. The concrete should be rather stiff so that it requires some tamping to get it to settle into the forms. A spade or thin board sharpened at one end may be used for working the concrete next to the form faces to obtain smooth, even surfaces. This operation pushes large pebbles away from the surface and releases any air that may have been trapped when the concrete was poured.

It is most desirable to complete a foundation or wall in one day's pouring if possible, in order to avoid construction seams. If it is necessary to stop work before a wall is finished, the concrete should be leveled in the forms and the surface roughened by scratching it or by placing large pebbles in it so that they project about halfway out of the concrete. This will help to secure a good bond between old and new layers of concrete when work is resumed. Before additional layers of concrete are poured, the roughened surface of the old concrete should be scrubbed to remove any dirt or scum which may have been deposited. Following this, the surface should be painted with a mixture of cement and water of the consistency of thick cream.

Top surfaces of all foundations and walls should be troweled smooth and level.

In warm weather the forms can be removed safely after three days. In cold weather, forms should not be removed for at least a week, preferably for ten days. It is best not to start the walls above a foundation for about two weeks after the foundation has been poured.

Concrete hardens much more rapidly if it is kept moist. Therefore, after the forms have been removed, it is a good plan to keep foundations and other concrete work covered with moist canvas or burlap

for several days after the pouring. This is a practice especially recommended during very warm and dry weather.

CONCRETE PILASTERS. Where pilasters are required, the foundation forms are merely widened to the desired dimensions and the concrete poured as explained in the foregoing material.

Concrete Block Foundations. When the concrete footing for concrete block foundations is sufficiently hard, the outline of the foundation can be marked using a chalk line or chalk. This line serves as a guide in placing the first row or course of blocks. It is a good suggestion to lay the first row of blocks without mortar all the way around the foundation in order to determine the joint spacing and whether or not any blocks have to be cut in order to piece out the required foundation on each side of the building. Vertical joints between blocks can vary safely from ¼″ to ⅜″, although the smaller joint is preferred.
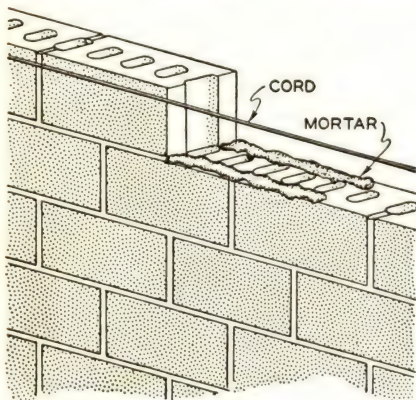
Fig. 20. Two Rows of Mortar Are Spread for Each Tier of Blocks

After the spacing and placement of the blocks has been decided upon, mortar, composed of one part cement and three parts sand mixed to a consistency where it spreads easily, is spread along the foundation in two parallel rows as shown in Fig. 20. The blocks should have their vertical edges buttered, as shown in Fig. 21, before being placed in position. Each block should be pressed firmly into its mortar bed so that the joint is not more than ½″ between the block and the footing and not more than ⅜″ between it and the previously laid block. Care should be taken to see that the blocks all follow the outline made along the footing and that the top edges of the blocks are all exactly the same height.

When the first row has been laid, the corners and intersections of the foundation should be built up at least several rows high if not to complete height. Care should be taken to break joints as shown in Fig. 22. Breaking the joints in the manner shown, binds the wall firmly together. Use the level often to keep the foundation plumb
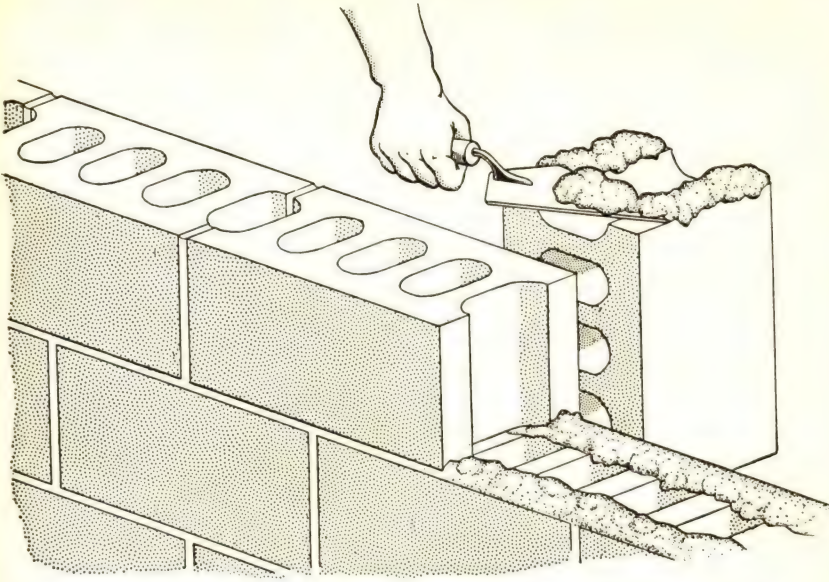
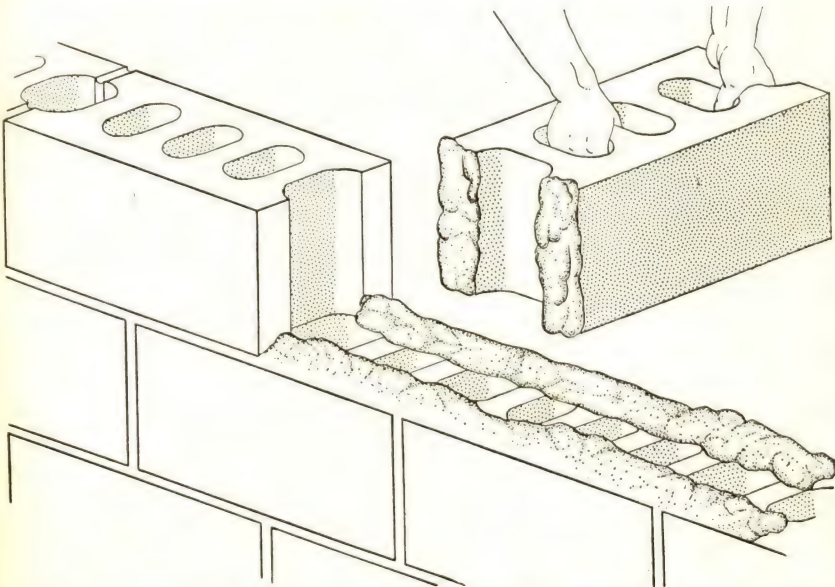Fig. 21. Vertical Edges of Blocks Are "Buttered" with Mortar before Laying

Fig. 22. Method of Holding Block in Placing It in Position against Block Previously Laid

and the top surfaces of the blocks even and level. As shown in Fig. 22, double rows of mortar are laid along the blocks and the end of each block is carefully buttered as it is lifted in place and pressed into position.

When the corners of the foundation have been built up, the intermediate rows of blocks on each side of the building are laid up to a

SOLE PLATE
MAY REST ON
TOP OF JOISTS
AND HEADERS

GROUT

HEADER

METAL TERMITE SHIELD

JOISTS
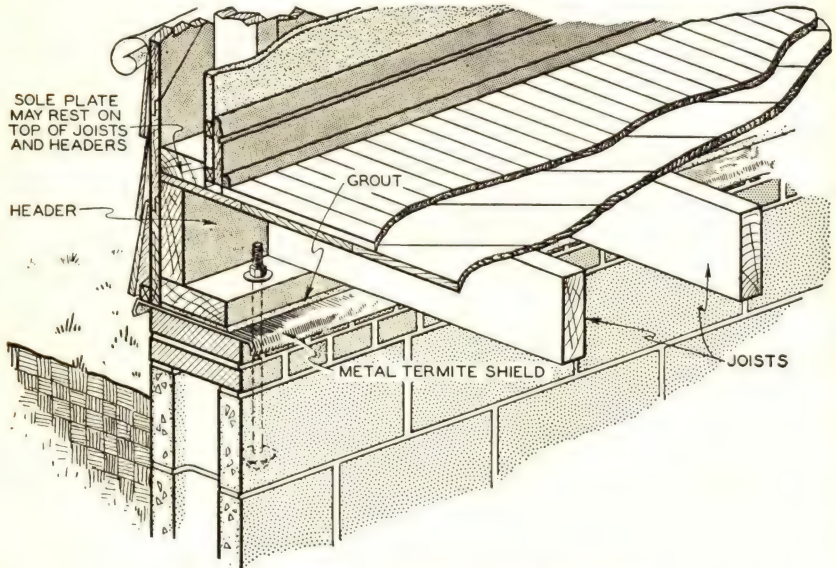
Fig. 23. Brick Cap for Concrete Block Foundation

chalk line which is stretched from corner to corner. The chalk line is moved up one course for each course laid. The outside top edge of each block must just touch this line as it is placed in position. In this manner the wall is made straight and the top of each row of blocks is at exactly the same level.

After the mortar between the joints has become quite stiff, it should be *pointed*. In foundation pointing, mortar is simply pressed firmly against the blocks by passing the trowel along the surfaces of the blocks in such a manner that it touches both blocks and covers the joint.

If frame walls are to be built on the foundations, the foundations must be capped all the way around with at least 4″ of brick or concrete. Fig. 23 shows how bricks have been used to form the cap.

The interior surface of concrete block foundations can be plastered by using a mix composed of one part cement and three parts sand. Such plaster is applied and smoothed with a steel trowel. The thickness of such plastering should not be more than ½ inch.

CONCRETE BLOCK PILASTERS. There are many patterns for laying concrete blocks so as to form pilasters. The pattern shown in Fig. 13 is typical. The first course is laid by spreading mortar on the footing so that there will be an adequate bed for the blocks. If the first course is like the top course shown in Fig. 13, the ends and sides of the blocks must be carefully buttered wherever they come in contact with other blocks. Each block must be carefully pressed into position so as to maintain the proper joint interval at all times. The level should be used often so as to keep the sides of the pilaster plumb and to take care that the tops of all blocks are all at exactly the same height.

If the block arrangement for the first course is the same as that shown at the top of the pilaster in Fig. 13, the arrangement for the second course is as shown at the right in Fig. 13. Each course is alternated between the two arrangements shown. Filling the holes or cells in each block with a mixture of 1:2:4 concrete adds materially to the strength of the completed pilaster.

Brick Foundations. Brick foundations may be laid as soon as the brick footings have been completed. The foundation is started by applying a cement mortar (1:3 mix) to the top of the footing at the corners where all unit masonry is always begun. Chalk lines or cords are set across batter boards in the marks indicating the face of the foundation. The layout should be carefully checked to avoid any possible errors.

The corners (intersections of side and end building lines) are projected to lower levels by means of a plumb bob. The corners are then laid up to a convenient height (about two or three feet). The use of ¼″ vertical and horizontal mortar joints is recommeded. Bricks are stepped up from the bottom row toward the corners to permit the proper bonding of the intermediate sections. After two corners have been built level and plumb to the desired height, a cord is fastened to hooks or nails which have been driven into the mortar joints at the top of the first course of bricks in each corner. This cord marks the top and outer edge of the first course to be laid between the two built-up

corners. Using this line as a guide, the bricks are laid on the footing in a full bed of mortar. To make certain that the bottom of the vertical joints will be filled, mortar is placed on the sides of the brick that will butt against the bricks in place. The brick is then worked into position by shoving, which squeezes the mortar into the joints. The line is moved up one course every time a course of brick has been completed. When units are cut for the placing of anchor bolts, all voids should be filled with mortar.

The recommended courses for brick foundations are shown in Fig. 14. The first course (stretchers) should be parallel to the face of the wall. The next course (headers) should be at right angles to the face of the wall. The next six courses should be parallel to the face of the wall or stretcher courses. From this point on, one course of headers should be alternated with six courses of stretchers. The spirit level or plumb rule should be used frequently to make certain that the foundation wall is perfectly vertical.

When the mortar has become quite stiff, the joints should be pointed with a small trowel. For foundations below grade level, the pointing can be done by passing the trowel along the joint, pressing the mortar into the joint flush with the outside edge of the bricks.

BRICK PILASTERS. The technique of brick masonry is followed in building brick pilasters.

Tile Foundations. Unlike concrete blocks, structural clay tile units can be laid with their cells in either a vertical or horizontal position. Tile foundations are laid following the same procedures described for the laying of concrete blocks.

TILE PILASTERS. Tile pilasters are laid using the same methods as employed when working with tile used for foundations.

Stone Foundations. Stone foundations can be started within a day or two after the footings have been laid.

Like concrete block and brick foundations, stone foundations should be built up first at the corners. The intermediate sections can then be laid, guided by a taut string stretched from one corner to another, course by course, as the laying proceeds. A cement mortar (1:3 mix) should be used for all parts of stone foundations which extend below grade level.

Aside from the quality of the stone and the mortar, the strength

of a rubble wall depends on the manner in which it is bonded or tied together by lapping the stones over each other. Stones which are long enough to extend entirely through the wall are called *bond stones*. This is shown in (A) of Fig. 18. These should occur every 4' to 5' in each course, or there should be one in at least every ten square feet of wall surface. Long stones should be used in the angles of a wall and should be laid alternately as headers and stretchers forming *quoins* as shown in (B) of Fig. 18. The largest and best stones should be reserved as quoins for the corners since this will be the weakest point in the wall.

In building a wall, make certain that the successive courses *break joints*. In other words, a vertical joint should not occur over a vertical joint of the preceding course. The wall should be roughly leveled off about every 2' in height, both horizontally and vertically. Horizontal joints should be kept as near level as possible. Continuous horizontal joints should be avoided in rubble work. A stone may be brought to a desired level by varying the thickness of the mortar joint. Much mortar can be saved through the use of *spalls*, or small pieces of stone, for chinking the spaces between large, irregular stones.

While a good wall face is desirable, strength should not be sacrificed for appearance. An example of this is the setting on edge of thin stones which are backed by rubble. The wall has an excellent appearance but is lacking in strength. All stones should extend into the wall 6" or more. Another fault among some masons is the practice of building the two faces of a wall with long, narrow stones, filling the space between them with dry stones and a little mortar. A wall of this kind is weak and should not be permitted.

A single large stone over an opening is called a lintel and acts as a beam. If the opening is wide, the stones above the lintel should be arranged so as to relieve it of some of its weight. Steel angles may be used to support the stonework over an opening if the span is less than 6' or **I** beams if the span is greater. This is shown in (C) of Fig. 18.

RATPROOFING

In some localities and especially on farms, it is necessary to make residences and barns ratproof. Fig. 24 illustrates several self-explanatory methods for masonry and frame structure ratproofing.

RATPROOFING FOR
FRAME CORN CRIBS

½" WIRE MESH

12" GALVANIZED SHEET
METAL 24 GAUGE

CONCRETE FLOOR

8" FILL

2'-6" MIN.

RATPROOFING FOR
FRAME BUILDINGS
ON MASONRY PIERS

CONCRETE
IN PLACE

PIER

GRADE

18"

RATPROOFING FOR
FRAME BUILDINGS
WITH LOW FOUNDATIONS

SPIKES
TO ANCHOR
CONCRETE

CONCRETE IN PLACE

2'-0"

CONCRETE FLOOR

REINFORCED
CONCRETE WALL

CONCRETE FLOOR

CONCRETE BLOCK OR
BUILDING TILE WALL

CONCRETE FLOOR

CONCRETE CONSTRUCTION
EFFECTIVELY SHUTS OUT RATS

Fig. 24. Recommended Methods for Ratproofing Buildings

Note: Self-check and review questions on the preceding material are included at the end of the chapter. Should you care to examine yourself on the subject matter just covered, turn to them now. Otherwise, continue with your reading.

THEORY OF WATERPROOFING

In many areas of the United States the soil is frequently and sometimes constantly damp or wet at ordinary basement depths. The degree of dampness or water in the soil varies in different areas. It depends on such factors as the amount of rainfall, proximity to streams and lakes, drainage facilities, type of soil, and elevation above sea level. For example, suppose that an area of land was located in a low-lying valley near a stream or lake, that the soil was clay, and that frequent rains were common. The soil constituting such land would most likely be exceedingly damp or even wet to the extent that water would quickly accumulate in any excavation such as that for a basement. On the other hand, a plot of ground located on high, well-drained land would have soil that would likely be only slightly damp, even though the rainfall for the area was above average.

When ordinary kinds of basement foundations are built in damp or wet soils, the insides of the foundations and the floor of the basement are apt to be damp and even wet. In extremely wet soils, the water forms an actual pressure on the outside walls of the foundations. In such cases, considerable seepage could easily take place through the foundations, footings, and floors to the extent that the basements would be of no value and might even constitute a danger. In any case, dampness or wet conditions in a basement are most undesirable, especially when basement spaces are to be used as laundries, recreation rooms, heater rooms, or for storage.

Ordinary cast-in-place concrete foundations and those built of individual masonry units are not truly moistureproof no matter how well they are built. Some slight dampness will seep through them in time, causing annoyances. The joints between footings and foundations and those between floors and foundations are not waterproof either. Thus, they constitute a point of easy entrance for dampness and water under the slightest pressure.

In order to prevent such annoyance and danger it is best to waterproof the outside surfaces of foundations and footings and to calk all

joints. This is easily done at the time the foundation is being built. The cost is not great, especially in view of the benefits obtained. If there is any evidence at all of dampness in the soil, waterproofing, as described in the following pages, should be carefully considered.

KINDS OF WATERPROOFING

There are many methods of waterproofing which may be used successfully. Those discussed here are typical and are recommended by average building codes, the Portland Cement Association, and by other agencies interested in good construction.
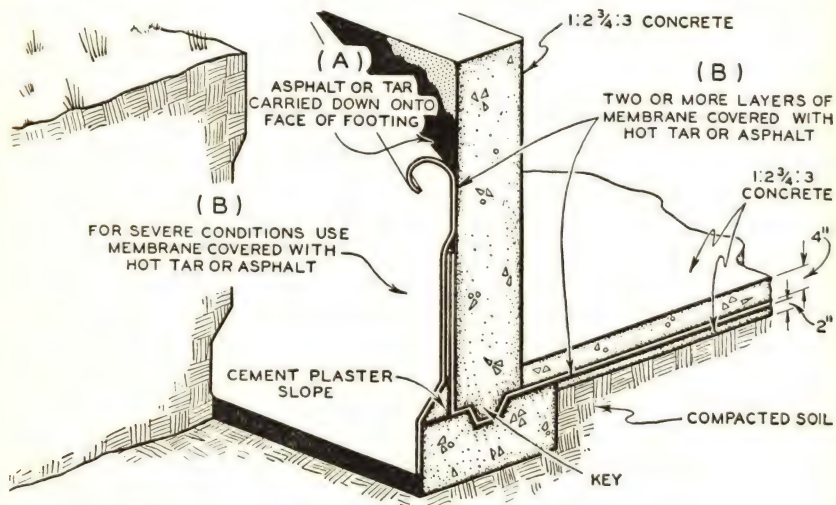
Fig. 25. Method of Waterproofing Foundation against Severe Ground-Water Pressure

Concrete Foundations. Perhaps the simplest form of waterproofing for foundations built in soil which is just damp, is to apply hot tar or asphaltum (asphalt) to the outside surfaces. These materials are moistureproof and constitute satisfactory waterproofing. This is shown in (A) of Fig. 25.

Where excessive dampness or severe conditions of water in the soil occur, the exterior surfaces of the foundation can be satisfactorily waterproofed as shown in (B) of Fig. 25. Two or more plies or layers of membrane (felt, for example) coated with tar or asphaltum are used. Note in Fig 25 that for extraordinary conditions the waterproof-

ing is applied at the joint between the footing and the foundation and that the floor is built in two layers with the waterproofing placed between the layers. In addition, note that a mix of $1:2\frac{3}{4}:3$ concrete can be used as a means of further retarding the flow of water through the foundation. Such concrete becomes dense in setting and, because of this characteristic, tends to prevent the flow or seepage of water through it. The slope at the point where the foundation meets the footing also helps to make that joint waterproof.
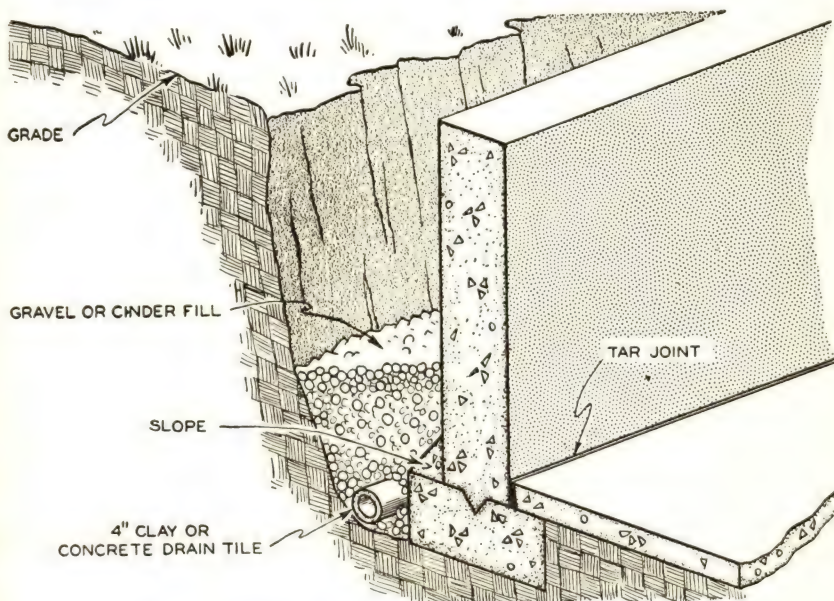
Fig. 26. Footing Drains for Use with All Kinds of Foundations

Another waterproofing method frequently used where there is excessive water in the soil is shown in Fig. 26. The clay or concrete tile is laid around all sides of the footing with a gravel or cinder fill covering it to the depth shown. The fill material allows the water to flow directly to the tile where it collects and drains off to some point away from the basement where it cannot do any harm. Occasionally, the water drains into a sump from which it is pumped to the regular sewer. When soil water conditions are really severe, drain tile are used in conjunction with the waterproofing methods explained in Fig. 25. Note the tar joint

between the floor and foundation in Fig. 26. This method of calking is effective and helps materially to keep moisture out of the basement in cases where no waterproofing materials were built into the floor.

Concrete Block, Brick, and Tile Foundations. When foundations are built of masonry units such as concrete block, brick, or clay tile units,
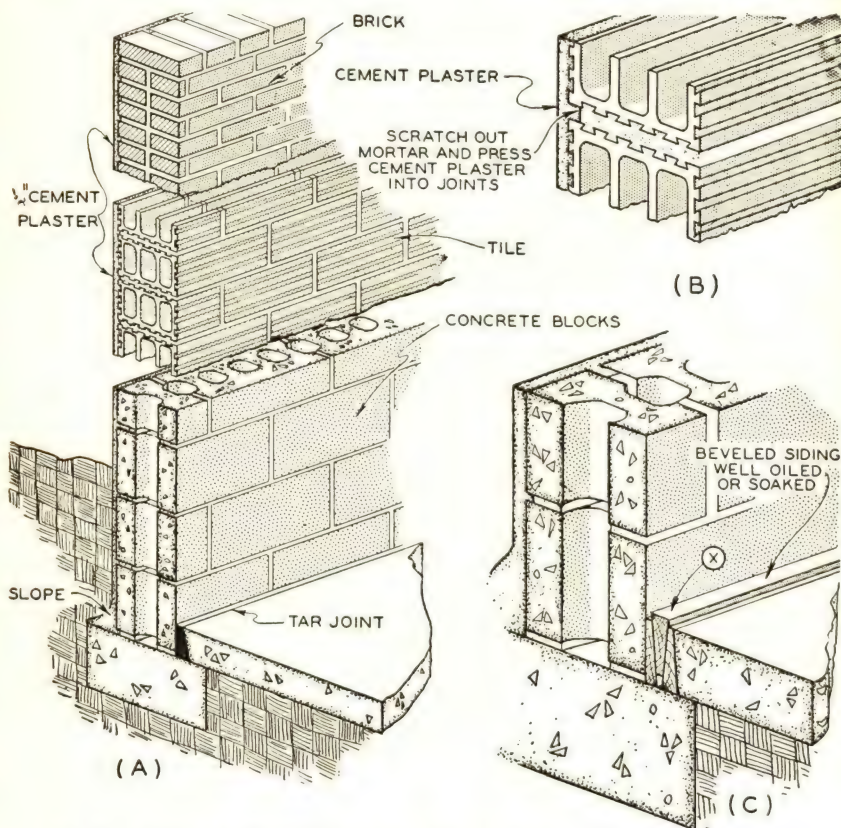
Fig. 27. Method for Waterproofing Foundations of Concrete Blocks or Clay Tile

there are many mortar joints through which dampness or water could enter a basement. For mild conditions of dampness, a single, thick coat of hot tar or asphalt applied to the exterior face of the foundation and footing will serve all waterproofing requirements.

When soil conditions are such that excessive water is present, a coat of cement plaster one-inch thick is applied to the exterior surface

of the foundation as shown in Fig. 27. This coating, together with the slope, serves to keep the water out. If the water conditions seem severe enough, the tar or asphalt plus membrane treatment just described can be used over the coat of cement plaster. The tar joint between the floor and the foundation also can be used. If this seems to be insufficient, the two-layer floor with the waterproofing material sandwiched between the concrete can be used along with the drain tile.
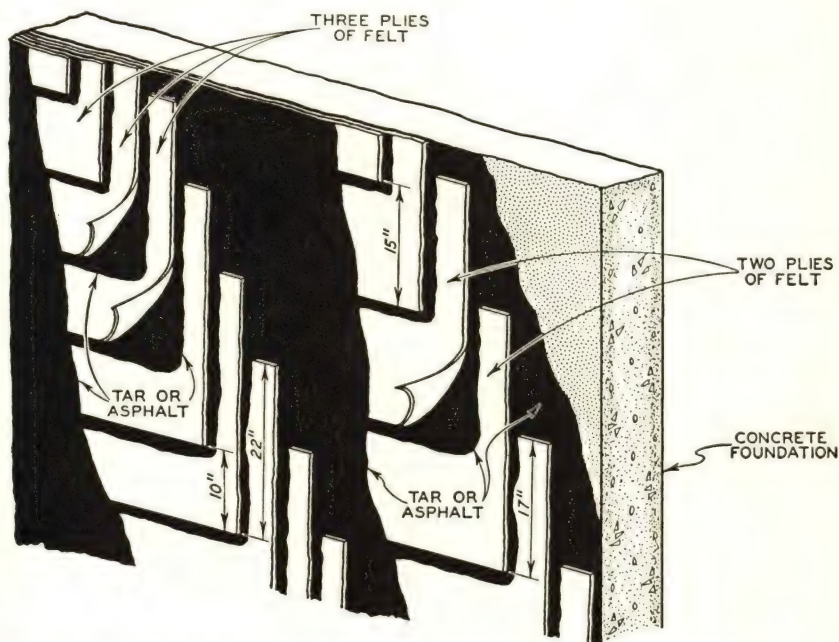
Fig. 28. Method of Lapping Three and Two Layers of Felt Waterproofing for Foundation

DESIGN OF WATERPROOFING

The design of waterproofing as described relative to Figs. 25 and 27 is evident. Fig. 28 shows a slightly different treatment of the membrane and tar or asphaltum treatment.

When drain tiles are used, the design of the system is important if it is to function correctly. Fig. 29 shows the plan view of a typical foundation and footing for a residence. The footing tile should be laid completely around the footing in such a manner that the whole system

slopes enough to insure flow at all times. If it is possible to run the water from the drainage system to a sewer as shown at X in Fig. 29, the footing tile should be laid so that there is a gradual downward slope from D to C to A and from D to E to F to G to A. In this manner, all water which collects in the tile lines will find its way to A and from there will run off into the sewer.
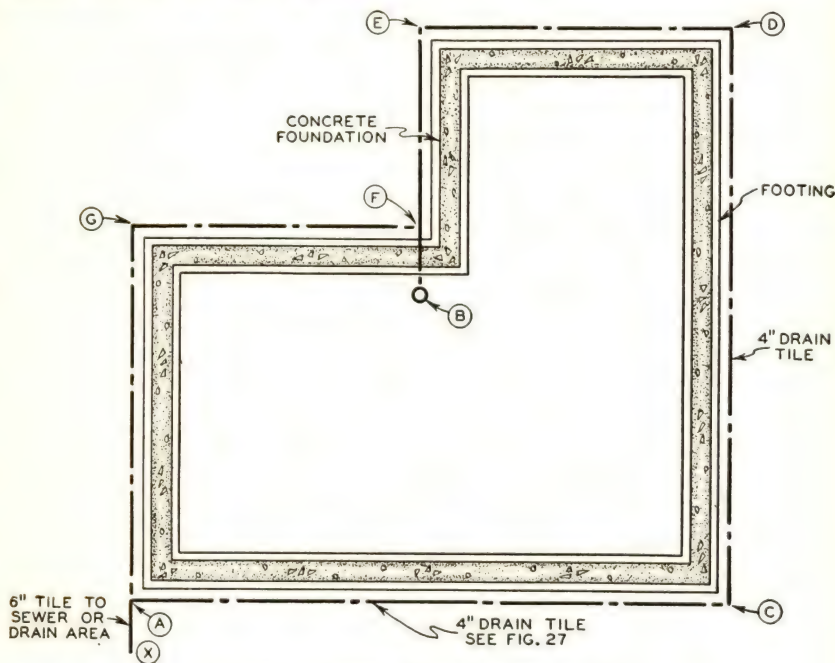
Fig. 29. Plan for Foundation Footing Drains

If the tile lines cannot be drained into a sewer because of their being below the sewer level or if there is no satisfactory place for drainage, a sump pump must be used as indicated at B in Fig. 29. In a case of this kind, all lines must slope so that B is the lowest point. From the sump at B, the water is pumped to a level high enough so that it will run off into the sewer. There are many dependable sump pumps on the market which should give satisfactory service.

Care should be taken not to plan the location of a basement in damp or wet soil unless the necessary tile lines can be drained as outlined in the foregoing.

HOW TO WATERPROOF

When only mild dampness must be considered, the tar or asphaltum should be heated to the point where it has a consistency similar to thick paint. This heating should be done in some sort of metal container which is large enough to contain sufficient material with which to work, yet at the same time is small enough to be moved easily from one place to another around the foundation. The tar is applied to the surface of the concrete with a regular tar mop or a brush of large size The application procedure is just like that of painting. The hot material is spread evenly over the surface of the foundation from the footing to the ground level. At least enough of the material should be applied so as to accumulate a coating of approximately $\frac{1}{16}''$ to $\frac{1}{8}''$ in thickness. Thinner coatings cannot be depended upon because of cracks and rough places in the surface of the concrete. The application should be carefully examined when it is finished to make certain that every inch of the foundation has been covered. Repeated applications build the waterproofing material to the required thickness. When backfilling is done around the foundation, care should be observed to avoid striking the waterproofing material with shovels and large pieces of soil or stones.

When membrane (usually felt) is to be applied in conjunction with tar, the surface of the foundation is first given a preliminary coating of tar. The membrane, generally supplied in rolls approximately 32" in width, is then placed along the bottom of the foundation immediately after a second application of the hot tar The membrane will stick firmly unless the tar is given a chance to cool. It will be noted from Fig. 28 that two or three plies are used in this method of waterproofing. If two plies are desired, the second layer of membrane is placed over the first so that it covers slightly more than half of the area of the first layer. The first layer is covered with hot tar before the second layer is stuck in position. If three plies are desired, the second ply should cover slightly more than a third of the first layer, the third ply slightly more than the second. The exact lapping dimensions are shown in Fig. 28. When the application of membrane has been completed, the entire surface is given one final coating of tar or asphaltum to completely cover the membrane.

Slopes from the footing to the foundation are made by using a

mixture of one part cement and not more than three parts sand. This mix should have only enough water added to it to make it stiff but workable. The height of the slope should be at least half the distance from the surface of the foundation to the edge of the footing.

When membrane is to be used between foundations and footings and between layers of floors as shown in Fig. 25, it should be applied before the foundation is poured and before the top layer of the floor is poured. The tar or asphaltum should be applied and the membrane lapped as was just explained.

For brick, tile, or concrete block foundations, the first procedure in effective waterproofing is the application of a thin coating of cement plaster approximately ½" in thickness as shown in Fig. 27. This cement plaster, or mortar, should be a 1:3 mix with just enough water added to facilitate its application with a steel trowel. The plaster will stick better if the joints between the individual masonry units have been made as shown in (B) and (C) of Fig. 27. The plaster application is started at the bottom of the foundation and is gradually worked upward to the ground level. Upward strokes with the steel trowel should be used and the thickness of the coat maintained as evenly as is possible. The work should be finished as smoothly as is feasible. If tar or asphaltum is to be applied over the plaster coat, at least one week during warm weather and two weeks during cold should be allowed for the plaster to set before the waterproofing operation is completed.

When it is desired to make a tar joint between a concrete floor and the foundation, space must be provided for the calking before the floor is poured. This is done by using beveled siding as shown in (C) in Fig. 27. If the siding is well oiled or soaped before the concrete is poured, it can be removed easily once the concrete has set. Note that the piece of siding marked X should be placed so that its thick edge is on top. This is to facilitate its removal. Once all the siding has been removed, hot tar is poured in this space. The shape of the calking prevents its being pushed out, should the floor expand.

Unless footing drains are laid with utmost care they will fail almost completely. One of the most important points in the laying of such drains is to make certain that they have the proper slope in order to insure that the water will flow through them rapidly enough to drain as quickly as it enters.

In order to understand the laying of drain tile, suppose that footing drains for the foundation shown in Fig. 29 are required.

First, it must be understood that at no place can the bottoms of the tile be lower than the bottom surface of the footings. Second, the tops of the tile should not be higher than the top surface of the footing.

The ground upon which the tile must be laid (see Fig. 27) was originally excavated to a depth equal to that of the footing. It is probable that on any job, enough soil will have fallen into the excavation by the time the foundations are complete to necessitate re-excavation to make room for the tile. In carrying out this re-excavation, more soil should be removed from the vicinity of *A*, in Fig. 29, than *D*
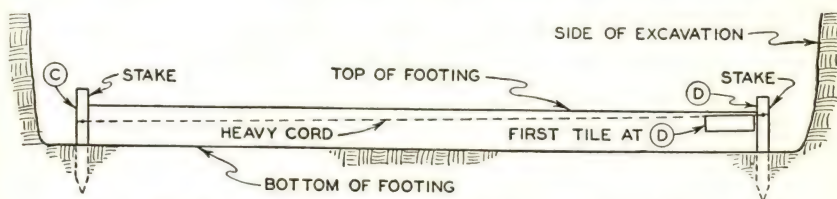
Fig. 30. Method for Determining Slope of Tile Drain Lines

because of the slope that will be required. It is probably the best practice to start the re-excavation at the high point, *D*. The depth to which to excavate can be determined by placing a length of tile near point *D*, pointing toward *C*. Only enough earth is removed so that the top of the tile is no higher than the top of the footing. The excavating is carried on in this manner, making certain that there is a gradual, uniform slope toward *A* and that the tile at *A* are not lower than the bottom of the footing. A practical method of determining the proper slope is as follows:

Fig. 30 shows the footing along foundation side *CD* in Fig. 29. Wood stakes should be driven at points *C* and *D* as shown. A heavy cord should be tied to the stake at *D* so that it just touches the top of the test piece of tile. The other end of the cord is fastened to stake *C* a distance not quite halfway down between the footing top and bottom. Some earth may have to be removed before the cord can be stretched between the two stakes. Once the cord is in position, the excavating continues, using the cord and the piece of test tile as a gauge for the correct depth.

For the tile line between C and A in Fig. 29, the same procedure is followed, except that the cord is fastened to the stake driven at A at a point near the bottom of the footing and left at the same point on the stake at C.

The same procedure is followed in laying out the lines on the other side of the foundation except that the slope from stake to stake must be more gradual since there are more sides to the foundation.

If no re-excavation is required, it will probably be necessary to backfill somewhat in order to obtain the proper slope to the line. The cord and stakes can be used when backfilling just as they were when making the re-excavation.
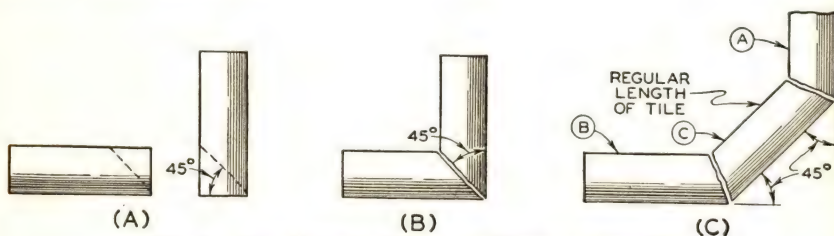
Fig. 31. Two Methods of Forming Elbows in Drain Tile

Tile used for footing drains should not be the bell-mouth joint variety. They should be laid roughly end to end so as to leave a small opening between lengths through which water may flow from the surrounding gravel bed. It is a good practice to lay pieces of tar paper over the tile at the joints before backfilling as a means of preventing any soil or other material from getting into the line.

As a general rule, such drain tile can be purchased only in straight lengths. When no elbows are available, corners may be formed by breaking tile with a hammer. Two methods of making a right-angle bend are shown in Fig. 31. At (A) is shown the dotted lines which indicate how two pieces of tile may be broken to form the elbow at (B). If a more gradual elbow is required, tile A, B, and C are cut at approximately 65° and assembled as shown in (C). The longer turn elbow is to be preferred since there is less chance for stoppages to occur.

Small stakes can be driven into the ground on either side of the tile, where necessary, to keep them in a straight line. Where backfilling is required to provide the correct slope, the soil should be tamped solidly to avoid any settlement at a later date.

In order that the seepage water can have easy access to the tile lines, gravel or cinders should be backfilled around the tile lines for a depth of at least 18″ above them. When placing the gravel around the lines, care should be taken not to move the tile or the tar paper over the joints. Above the gravel fill, ordinary soil is used to complete the backfilling. However, this soil should not be tamped because of the possibility of disturbing the alignment of the drainage line by so doing. A gradual settling of the backfill will take care of the necessary compacting of the soil.

From point *A* in Fig. 29, tile having bell-mouthed joints should be used to carry the water either to a sewer or to a place where it may be disposed of conveniently and safely. Joints of this section of tile should be cemented with a 1:3 mix of cement and sand. This tile line also must slope continuously. The slope can be accomplished by making the trench gradually deeper as it is excavated from *A* to the disposal point.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

FOUNDATIONS

DO YOU KNOW

1. How much of each of the floors in a residence is supported by the foundation?

Answer. The foundation supports that portion of each floor halfway between the outside wall and the next support which is generally an interior partition such as *GK* or *KH* in Fig. 1.

2. Why it would be poor practice to build a permanent residence directly upon the soil without foundations?

Answer. Because the residence would settle, wood parts would rot, termites would attack wood parts, and the rooms would be damp.

3. What the advantages are of poured-in-place concrete foundations?

Answer. Except for the construction of the formwork, only cheap unskilled labor is needed. In addition, there are no joints through which water might find its way into the basement.

4. What disadvantage there is in building a poured-in-place concrete foundation?

Answer. Only that expensive lumber and skilled labor are required to build the necessary forms.

5. What the advantages are of concrete block foundations?

Answer. They are inexpensive, can be laid quickly, do not require drying time, and do not require forms.

6. What kind of brick should be used to build foundations?

Answer. The bricks should be hard burned.

7. What kind of mortar should always be used for concrete block and brick foundations?

Answer. The mortar should be a mix of Portland cement and sand in a 1:3 ratio.

8. What size mortar joint is recommended for brick foundations?

Answer. A joint not greater than ¼ inch.

9. How much oats weigh per cubic foot?

Answer. 26 pounds.

10. How poured-in-place concrete foundations are keyed to the footings?

Answer. By a **V** shaped slot in the footing.

11. How the tops of concrete block foundations must be finished for a frame house?

Answer. The top should be finished with 4″ of brick or poured-in-place concrete.

12. How areaway walls are fastened to the main foundation when they are not poured as an integral unit?

Answer. By reinforced steel which is embedded in both the foundation and the areaway wall.

13. What shape the bearing surfaces of stones should be in rubble foundations?

Answer. Flat.

14. What the allowed compressive strength is for concrete blocks when Portland cement mortar is used?

Answer. 80 pounds per square inch.

15. What the allowed compressive strength for brickwork is when Portland cement mortar is used?

Answer. 200 pounds per square inch.

REVIEW QUESTIONS

1. How is the load per lineal foot determined which a foundation must support?

2. Name four main purposes of a foundation.

3. What size mortar joints are recommended for concrete block foundations?

4. What forces and loads do foundations have to resist?

5. Explain the procedure for building a concrete block foundation.

6. What thickness should a poured-in-place concrete foundation be for a two story residence?

7. What are pockets and where are they used in a foundation?

8. What is the recommended total live and dead load for first floors in a residence?

9. Explain how frost action could injure a building if the foundations were not deep enough in the ground.

10. What are the purposes of pilasters?

11. How may areaways be drained?

12. What determines the size of a pilaster?

13. How are frame walls fastened to the tops of foundations?

14. What is the recommended way in which to lay bricks in a brick foundation?

15. What special bearing is provided for joists in tile walls or foundations?

WATERPROOFING

DO YOU KNOW

1. How concrete floors can be waterproofed in exceptionally wet soil?

Answer. By pouring them in two layers, putting several plies of membrane and tar or asphaltum between them.

2. What the lowest point is at which footing tile can be laid?

Answer. The bottom edge of the footing.

3. How tile foundations can be waterproofed in damp soil?

Answer. By applying a half-inch coat of cement plaster to the exterior face of the foundation, followed by a mopping with hot tar or asphaltum.

4. What precautions should be taken when applying hot tar or asphaltum to concrete foundations?

Answer. Care should be taken to apply the tar at least $\frac{1}{16}''$ in thickness and to spread it uniformly over smooth and rough surfaces alike.

5. What "slopes" are and how they are employed to aid in the waterproofing of foundations?

Answer. A slope is composed of cement plaster and is applied at the exterior point where the foundation meets the footing. Its object is to drain water away from the joint between footing and foundation.

REVIEW QUESTIONS

1. Why are pebbles and gravel backfilled over footing tile drains?

2. What is a sump?

3. Explain how to obtain the correct slope when laying footing tile.

4. What special attention is given to joints in concrete block foundations prior to waterproofing them?

5. What type of joint is required for footing tile?

6. Where is tar paper used in laying footing tile?

7. Explain how to excavate for footing tile.

8. Explain how to apply two-ply felt and tar or asphaltum.

9. Explain how joints between concrete floors and foundations can be waterproofed.

10. What concrete mix is recommended for concrete foundations in a very wet soil?

Beams and Lintels and Their Uses

QUESTIONS CHAPTER IV WILL ANSWER FOR YOU

1. *What are the factors determining the selection of a beam for any building?*
2. *What is the difference in strength of a solid wood beam and one which has been built up?*
3. *What characteristic of any beam must be taken into consideration even though it is capable of supporting the load you wish to place on it?*
4. *How are loads calculated for a lintel?*
5. *How is steel reinforcing used to the best advantage in making concrete lintels?*

INTRODUCTION TO CHAPTER IV

The great importance of beams and lintels will be appreciated more readily and their study in the following pages made easier if a brief consideration is given to their development and the effect they have had on architecture.

One of the earliest examples of the lintel is to be found in the megalithic structures of Europe and Asia. Perhaps the most widely known of these monuments is the group at Stonehenge, on Salisbury Plain, England. Wooden beams placed atop pilings were used by the Stone Age Lake Dwellers in building community housing projects such as those which were located in the waters of Switzerland's lakes. However, architecture is considered to have had its beginning in the more permanent dwellings and monuments of the ancient Egyptians and Chaldeans. The domestic buildings of these people were constructed of sun-dried clay brick, the rafters and lintels being made of palm tree trunks. Stone lintels and crude, inverted, **V** shaped arches were used in the sepulchral chambers of the Pyramids which were built between the years 3969–3784 B.C. during a period known as the Ancient Empire. Stone lintels also were used extensively in all temples built at a later date. As a matter of fact, the Egyptians used only the one idea of the lintel and post with the result that all enclosed spaces of any kind became a forest of columns. To a large extent, this was true also of Greek and Roman architecture.

Transition from the post and lintel to the pointed arch made possible a greater clear opening and for this reason became an imposing feature of entrances and porticoes. But it was not until the development of the steel beam that architecture took a step in a new direction. It is interesting to note that the great progress made by modern architecture is due to the use of the ferroconcrete or structural steel skeleton in present-day buildings.

Without the great strength of the steel beam and steel-reinforced concrete, contemporary buildings would have the same limitations in design and appearance as those built two centuries ago. The skyscraper would be a structural impossibility. The tremendous floor areas, completely devoid of columns or posts, as found in large factories, gymnasiums, stadiums, hangars for lighter-than-air craft, etc., would be equally remote from reality. The fully cantilevered balconies in theaters and auditoriums would be an architect's dream, while the audience continued to crane its collective neck around thick posts. Even the simplest residence would have a basement choked with bearing partitions and supporting columns.

The purpose of this chapter is to acquaint you with the beam and lintel problems which arise during the design and construction of small buildings. A careful description and analysis of the loads and stresses resulting from these problems pave the way for an understanding of the method used in selecting the proper beam or lintel for the job. You will learn the various kinds and uses of the more common steel beams, wood beams, and lintels made of steel, wood, reinforced concrete, and reinforced clay tile. The placing of these beams and lintels is described for you. At the end of the chapter are self-check questions which cover the important points you have read. If you are able to answer these questions when you have finished reading the chapter, you will have an adequate foundation on which to build practical experience in dealing with beams.

IMPORTANCE OF BEAMS AND LINTELS

In the construction of residential, farm, apartment, store, industrial, and other small buildings, many various kinds of beams must be considered. In fact, a large portion of all such construction work considered from the mason's point of view has to do with the design, setting, and construction of these beams. Generally speaking, when structures have been designed by an architect, the specifications for all beams are given in the blueprints or working drawings. However, the mason occasionally is required to design beams as well as place or build them. For this reason, this chapter will show as far as is possible without the use of intricate mathematics, the design of all simple types of beams, the various common types of beams, how they are supported, how they are constructed, and how they are placed or set. The first portion of the chapter is given over to the study of the heavier types of beams such as are used in supporting floors. The remainder of the chapter deals with lintels and other small beams.

THEORY OF BEAMS

The outside walls of a building support a large part of the weight of the building plus its contents. This weight first occurs at the top of

the walls where the roof is supported and gradually increases in a vertical plane from the roof line and the foundation. That weight not supported by the outside walls must be supported by interior partitions.

Fig. 1 is a rough sketch showing a section of a two story building having an attic and a basement. An examination of the sketch will show that the outside walls *AG* and *SJ* must support the weight of the roof. The structural materials in the roof plus the accumulations of
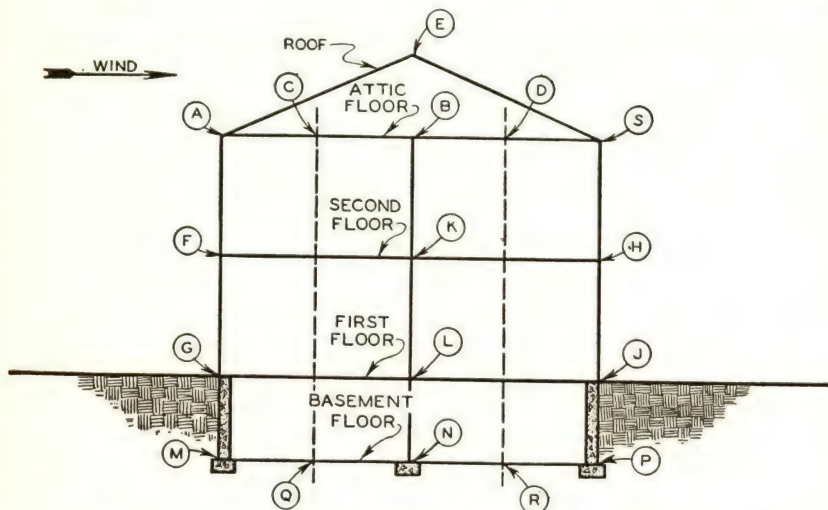
Fig. 1. Walls and Partitions Support Weight of a Building and Its Contents

snow during the winter months in the northern climates, represent a considerable total weight. When architects speak of weight in this respect, they refer to it as a *load* or loads of a definite weight in pounds. The necessity for such a generalized term is understandable when the force of winds, for example, is considered.

If a roof is steep, the large area involved is subject to what is called wind pressure. Such pressure is caused by wind blowing against the roof. During storms, a steep roof may be subjected to a wind pressure of twenty pounds or more per square foot of roof. For a large roof, such a pressure would constitute many pounds of pressure. If the wind blew a gale from the left as indicated in Fig. 1, then wall *SJ* would have to support many additional pounds of pressure. The wind would tend to push the roof to the right and wall *SJ* would resist such a movement.

This wind pressure is not a true weight, so it is called a load of so many pounds per square foot. The actual weights involved are also called loads to facilitate calculations.

The attic floor in Fig. 1 is supported partly by the outside walls and partly by the interior wall (bearing partition) *BK*. This is because it is not practical to use floor joists which are long enough to extend from *A* to *S*. The portion of the attic floor load supported by wall *AG* is equal to the distance from *A* to *C*. In like manner wall *SJ* supports that part of the attic floor load between *D* and *S*. The portion of the attic floor load between *C* and *D* is supported by bearing partition *BK*. Architects and engineers say that an outside wall, for example, supports the attic floor load for half of the distance to the next support.

Second floor loads are supported in a like manner by the outside walls but the load is now greater than at the attic floor level. Bearing partition *KL* supports its share of the second floor plus the load which bearing partition *BK* carries from the attic floor.

Similarly, the foundations support their share of the first floor loads in addition to the loads from above. The basement bearing partition *LN* carries the combined loads from bearing partition *KL* as well as its share of the first floor.

Thus you can see that the loads on outside walls, on foundations, and on bearing partitions gradually increase from the top of the building down to the footings. The loads amount to so much per lineal foot because the weights are fairly equally distributed.

If for any reason it is desirable to omit a section of an outside wall or a bearing partition, some means must be provided to carry the load over the opening. Beams are used for this purpose. A beam, therefore, is a structural device for supporting loads in the absence of walls or bearing partitions. Beams frequently are employed to strengthen concrete floors, thereby allowing them to be built much thinner than would be possible if beams had not been used. Joists can be classed as beams because they support floors.

KINDS AND USES OF BEAMS

Steel Beams. Practically all standard steel shapes are used as beams. Among the most common are angles, **I**'s, channels, and **H**'s. For light loads, angles placed back to back in pairs are used frequently. For

heavier loads, **I**'s, channels, and **H**'s are better because of their shape and added strength. However, in many cases, the selection of shape is simply a matter of the designer's preference rather than one of an engineering nature. In other cases, space limitation is the deciding factor governing the selection of shape. For example, a channel with its web horizontal occupies much less space vertically than an **I** or **H** of the same strength.

Fig. 2 is a pictorial sketch of a residence with masonry walls and five sections of beams used in the building. The beams and their locations in the walls of the building are indicated by the same letter. At this point, only letters *A*, *C*, *D*, and *E* will be considered.

At *A* in the upper portion of Fig. 2 are shown two channels which are used as a beam to support a section of the second floor which has no first floor walls to carry the load. If no beam were used, the outside walls of that section would have to be carried down to the foundation.

At *C*, two channels are used as a beam to carry the concrete block wall's load over a window alcove opening in the wall. An angle carries the weight of the brick veneer over the opening. This window alcove would be impossible without the use of beams to carry the loads over the openings.

The perspective of the residence indicates it has a two-car basement garage. Such a garage requires a large door and means there must be a large opening in the foundation. Since the foundation supports the outside wall above it, a beam is required to carry the load in the absence of the foundation. At *E* is shown the location of the foundation opening and the detailed section shows the use of the two **I** beams. Note that these **I** beams carry the load of the concrete block and brick veneer parts of the outside wall, part of the concrete floor over the garage, and part of the concrete terrace floor.

The angle and channel at *D* support the short stone wall directly over the garage doors and part of the concrete terrace floor.

Fig. 3 is a group of rough sketches of the first floor and basement plans of a much smaller brick residence than the one shown in Fig. 2. Note *AB* in the first floor plan of Fig. 3. This is a large opening in the outside wall to allow a ceiling-height archway between the living room and sun porch. In order to carry the loads from the outside wall above the archway, an **I** beam is placed over the opening.
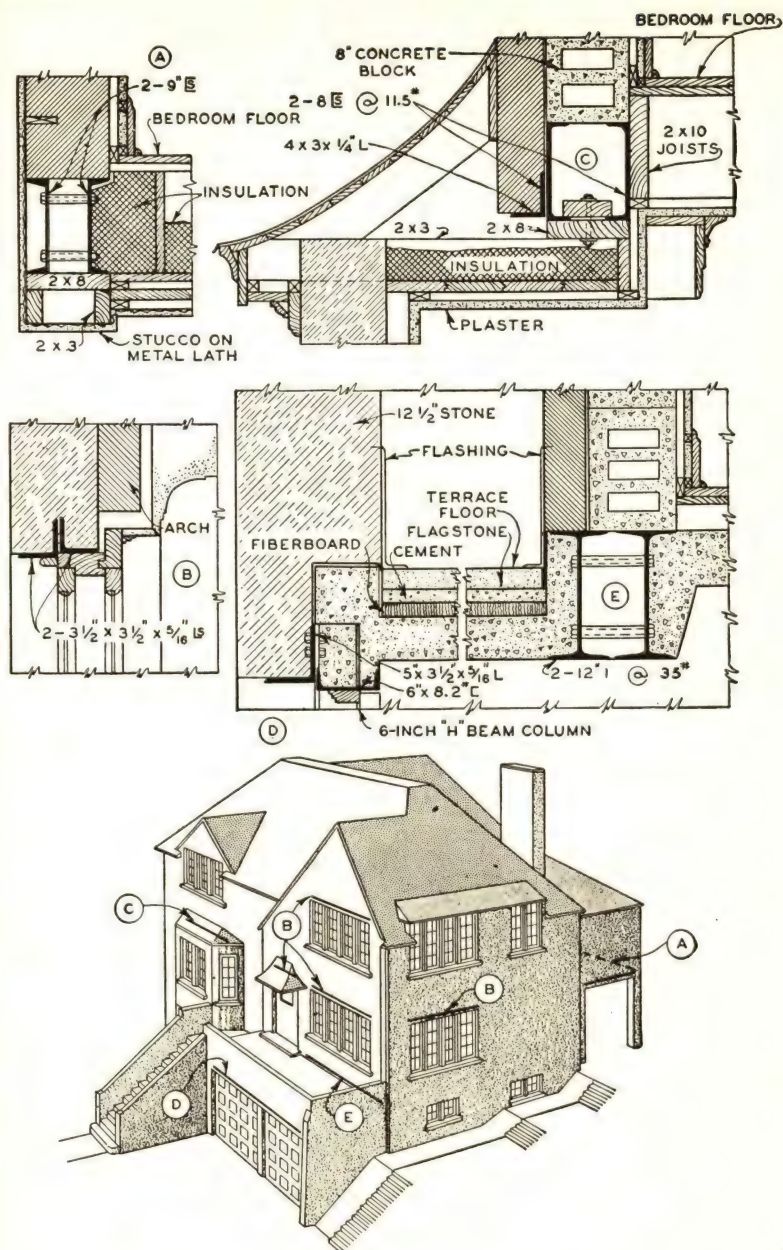
Fig. 2. Use of Beams in Residence

Next, note the load-bearing partition CD in the first floor plan. This partition supports part of the second floor and attic in much the same manner as the load-bearing partitions in Fig. 1. In the basement under partition CD, there must either be another bearing partition or a beam. Either one would be adequate. However, in order to keep the basement clear of any partitions, an **I** beam should be used from E to F. In like manner, angles can be used between GJ and HK in the basement to avoid partitions under bearing partitions GJ and HK in the first floor plan.
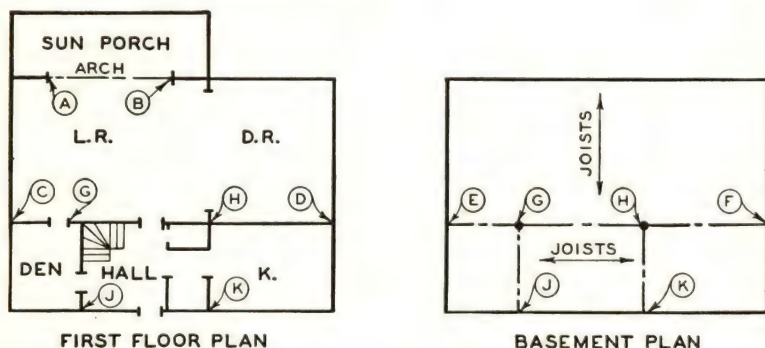
Fig. 3. Plan View of Residence Showing Use of Beams

Fig. 4 shows rough sketches of a section and plan for a dairy barn. In the section, the line from A to B represents the haymow floor. This floor must be supported at C and D (EF and GH in the plan) because of the heavy loads caused by the hay and the fireproof construction of the concrete floor. This means that there must either be bearing partitions on the first floor or beams. Since partitions would be objectionable for a dairy barn, beams are used.

The pictorial sketch in Fig. 4 shows how **I** beams could be used for the main beams at EF and GH in the plan and also how **I** beams could be used to support the concrete floor.

Fig. 5 at B illustrates the use of **I** beams in place of bearing partitions in supporting the concrete roof of a one story dairy barn.

Rough sketches of the first floor and basement plans of an apartment building are shown in Fig. 6. Following the same principle explained for Fig. 1, **I** beams can be used at A and B and along C, D, E,

F, G, and *H* in the basement to avoid bearing partitions. The same letters are placed on the first floor plan to help the reader visualize the location of these beams.

At Fig. 7 are shown rough sketches for the first floor and basement plan of a bakery and store building. The second floor, which is not
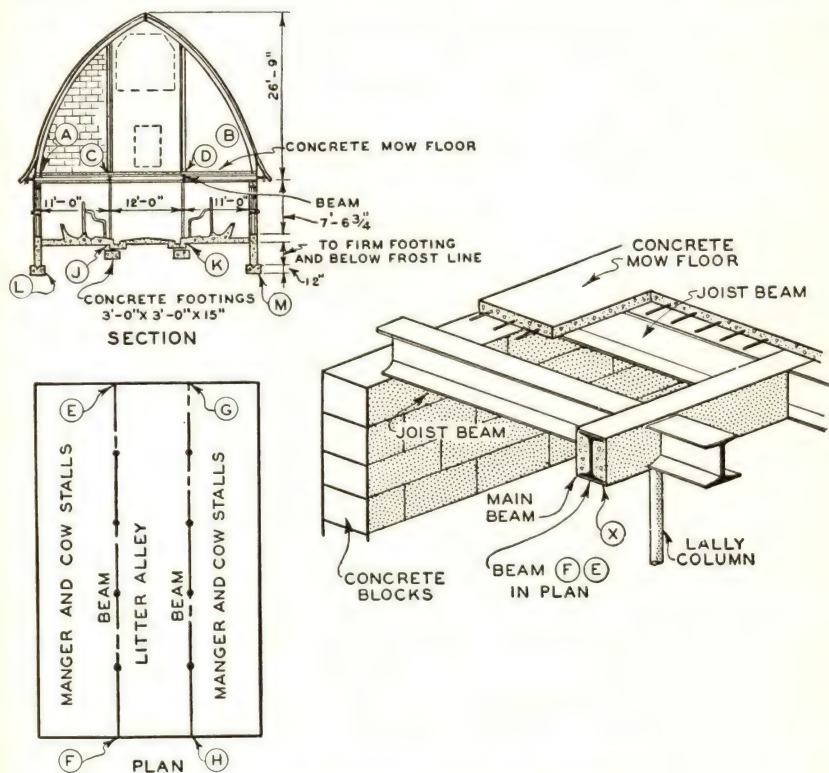
Fig. 4. Use of Beams in a Typical Dairy Barn

shown, contains an apartment for living quarters. In the first floor plan, the **I** beams shown at *A, B,* and *C* support the second floor apartment and thus avoid the necessity of load-bearing partitions in the store. The **I** beams at *D, E,* and *F* support the roof over the baking room and garage and avoid bearing partitions in them. Note that the **I** beams at *A, B,* and *C* which support the second floor apartment, have their ends (bearing surfaces) supported by steel plates or short
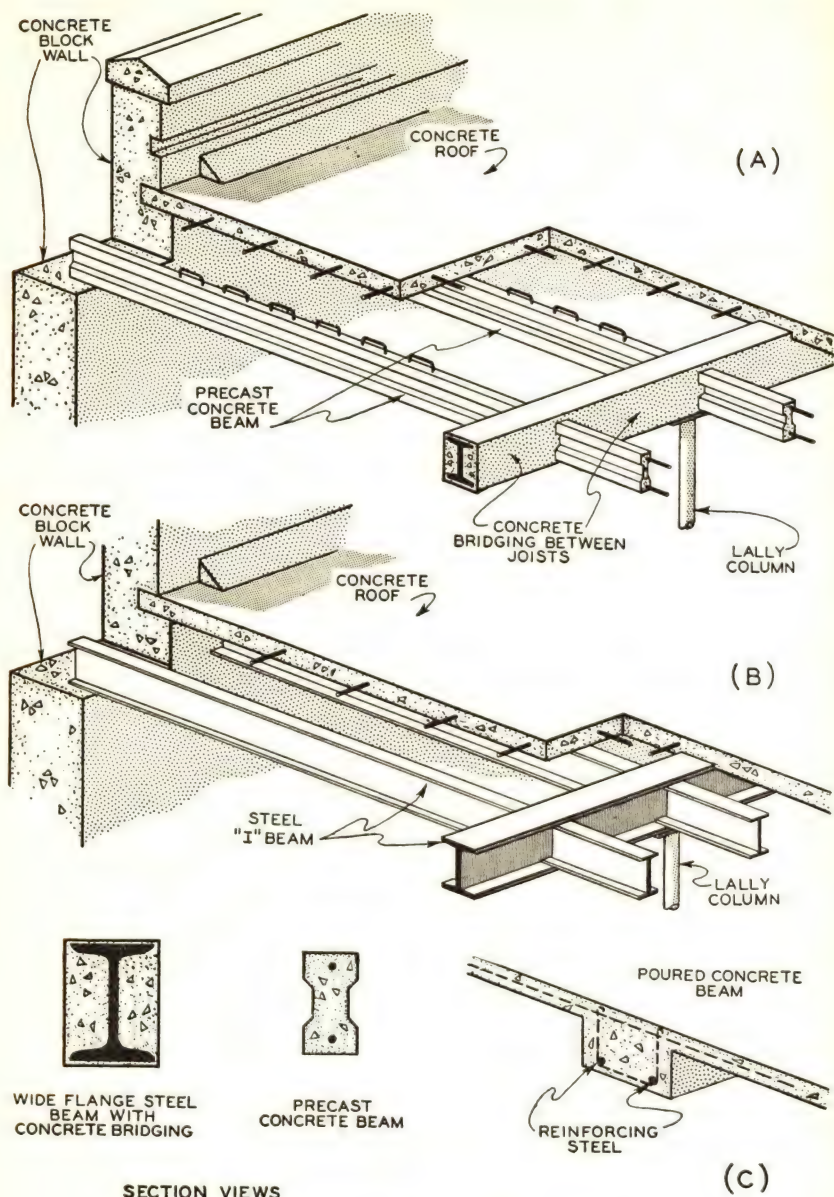
Fig. 5. Roof Beams for One Story Dairy Barn

I beams which are embedded in the brick walls. These plates and short beams distribute the load from the main beams over a larger area and avoid the necessity of pilasters. In the basement plan, the **I** beams between *H* and *J* support the loads from the store floor and thus avoid bearing partitions in the basement.
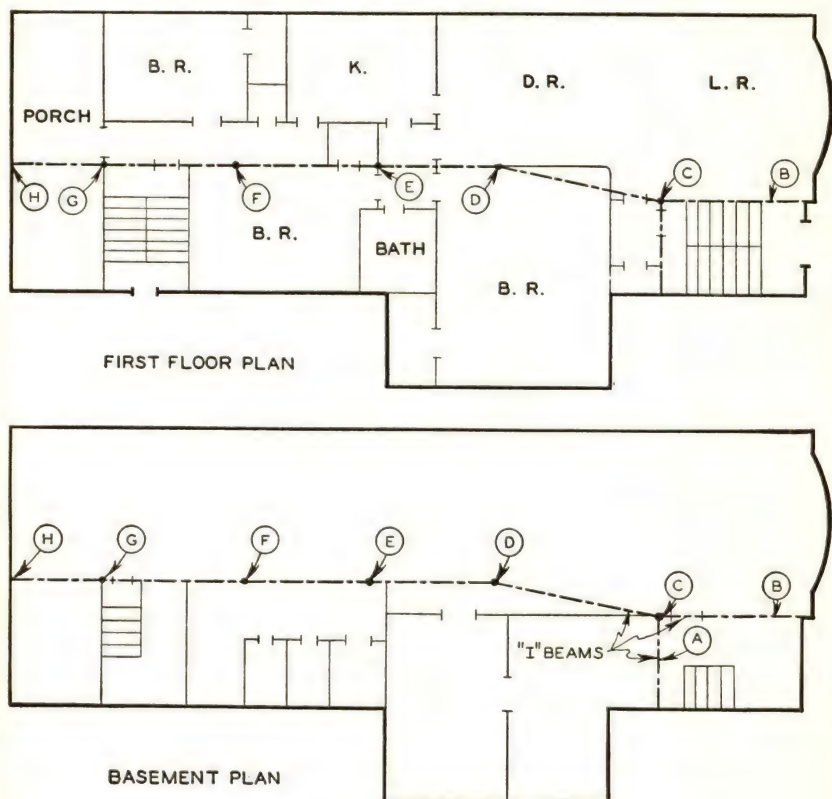
Fig. 6. Use of Beams in Apartment Building

Reinforced Concrete Beams. There are many kinds of reinforced concrete beams. Any of them can be used to advantage. The simplest variety is the precast beam which is frequently used as a joist or rafter in masonry buildings. In (A) of Fig. 5 is an illustration of the use of precast concrete beams. They are employed in the fireproof roof of a one story dairy barn. Such beams can be used also as joists in place of **I** beams as shown in Fig. 4.

Steel beams with wide flanges are sometimes used in connection with precast beams as shown in (A) of Fig. 5. In this particular case, the areas between the flanges are filled with concrete to serve as a bridging between joists or rafters.

In (C) of Fig. 5 is shown the use of fully reinforced concrete beams as an integral part of the concrete roof for a firesafe dairy barn.
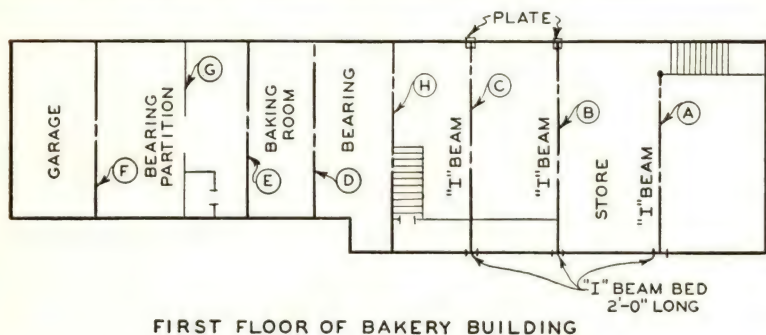
FIRST FLOOR OF BAKERY BUILDING
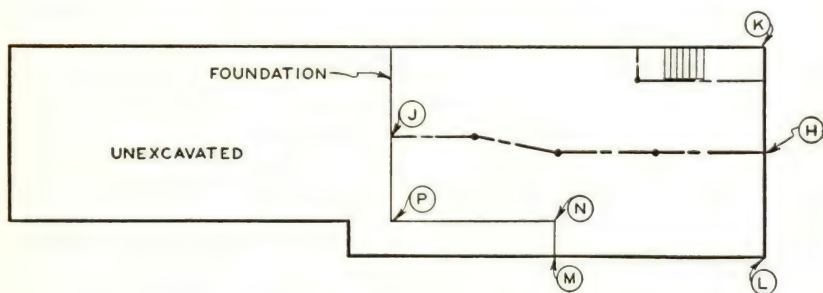
BASEMENT PLAN OF BAKERY BUILDING

Fig. 7. Use of Beams in Store Building

This same construction could be used for the haymow floor of the dairy barn shown in Fig. 4.

Fully reinforced concrete beams can be made in any shape desirable. In addition, they may be designed with various amounts of reinforcing steel to support any given load. The beams illustrated in Fig. 8 are typical as to shape and type of steel reinforcing employed. The reinforcing varies with the shape and loads supported by the beams. The beam shown in (C) of Fig. 5 is a **T** beam, generally used for concrete floor construction.

Reinforced concrete beams can be used in place of the steel beams described and illustrated in Figs. 2, 3, 6, and 7. Unless full concrete floors are required or unless other framing members are of concrete, it is more economical, quicker, and just as satisfactory to use steel beams.

Wood Beams. Masons are not particularly interested in wood beams because their manufacture and installation are usually the carpenter's job. However, there are occasions when masons must handle them, and for this reason they are explained here.
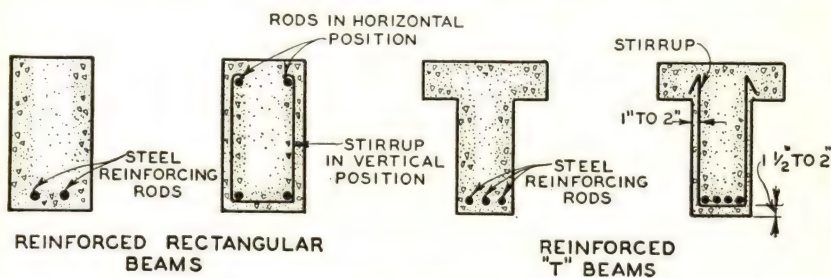
Fig. 8. Cross Sections of Reinforced Concrete Beams

There are three general classes of wood beams: (1) solid or one piece, (2) built up, (3) built up and including a steel plate for additional strength or stiffness.

SOLID OR ONE-PIECE BEAMS. Solid wood beams can be purchased in many sizes, all of which are multiples of 2, such as 4 x 4, 4 x 6, 4 x 8, 4 x 10, etc. The widths also change in multiples of 2, such as 4 x 6, 6 x 6, 4 x 12, 6 x 12, 8 x 12, and so on. The larger sizes, especially in long lengths, are difficult to obtain and are expensive. However, there are cases where the use of wood beams even in large sizes is more economical or desirable than steel or reinforced concrete.

BUILT-UP BEAMS. Built-up wood beams are commonly made by spiking two or more 2 x 8's, or other size lumber, firmly together. This type of beam is illustrated in (A) and (B) of Fig. 9. It does not quite equal the strength of a solid wood beam but is extensively used, especially in wood frame residences in much the same manner as was explained for **I** beams in Fig. 3.

The built-up compound Clarke beam shown in (C) of Fig. 9 is easily built and has about 75 per cent of the efficiency of a solid

wood beam of the same size. However, its tendency to deflect or bend under loads is almost twice that of solid beams so its use in plastered ceilings should be carefully considered.

FLITCHED BEAMS. The flitched or wood and steel composite beam is shown at (D) in Fig. 9. It is easily made using 2 x 8 lumber, or other sizes, together with a wrought iron or steel plate and bolts.

THREE 2x8'S
BUILT-UP 6x8 BEAM
(A)

THREE 2x4'S
BUILT-UP 4x6 BEAM
(B)

1½" TO 2"   ½" TO ¾" BOLTS
WASHER
10d NAILS
DIAGONALS RUN IN OPPOSITE DIRECTIONS ON EACH SIDE
CLARKE BEAM
(C)

WROUGHT IRON PLATE   ½" TO ¾" BOLTS
WASHER
FLITCH BEAM
(D)
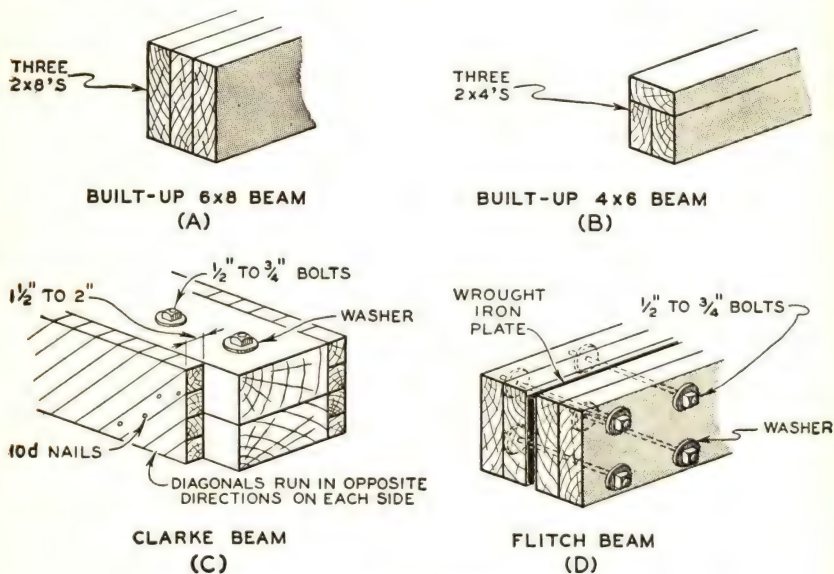
Fig. 9. Built-Up Wood Beams

This beam is used extensively in remodeling where bearing partitions are to be removed and where **I** beams could not be installed without tearing out joists.

Both the Clarke and flitched beams can be made using materials of various sizes and strengths.

HOW TO SELECT BEAMS

In selecting any type of beam, the load it must carry is determined and a shape and size then selected which will result in producing a beam sufficiently strong to carry the load without too much deflection or bending. In this book, only the designs of simple steel and wood beams will be discussed. The design of concrete beams re-

quires intricate mathematics. If their use is anticipated, a structural engineer should be consulted, especially if the beams will be expected to carry heavy loads.

Selection of Steel Beams. In order to become familiar with the selection of steel beams, the following typical examples will be discussed.
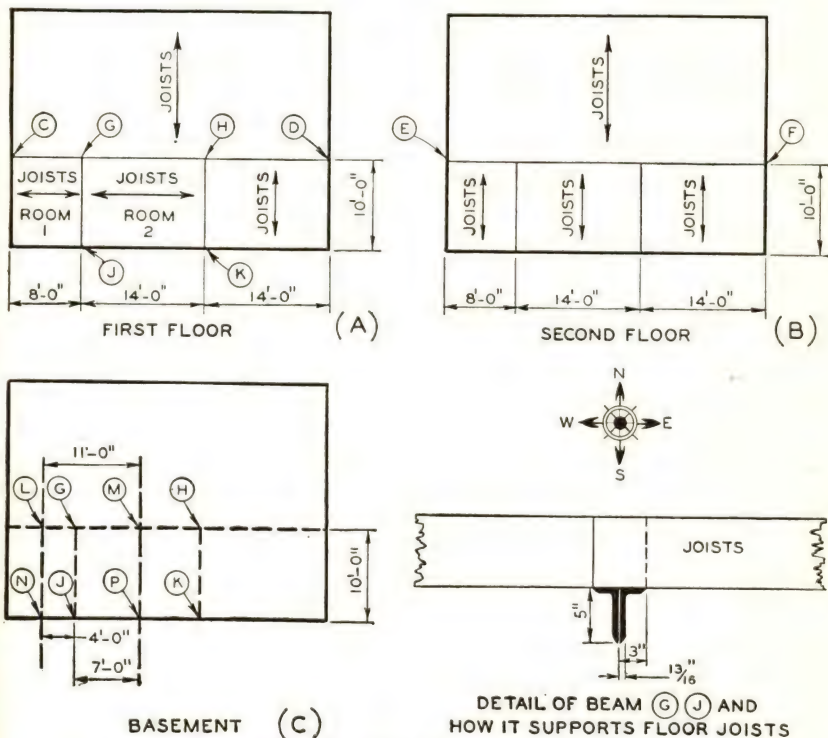
Fig. 10. Factors Affecting Selection of Steel Angle Beam for Residence

The rough sketches in Fig. 10 show more details of the beam *GJ* which was shown in Fig. 3. By studying (A) in Fig. 10, it can be seen that the beam at *GJ* must support half of the floor load on either side of it plus the weight of the partition between rooms *1* and *2*. This beam is not required to support any second floor loads because those joists run in the other direction and are supported by the south outside wall and the long bearing partition marked *EF*. See (B) of Fig. 10. In other words, this beam supports only the floor load from the

area marked *LMNP* as shown in (C) of Fig. 10. This area is 11′ 0″ by 10′ 0″ and therefore has an area of 110 square feet.

When calculating the loads from floor areas, live and dead loads must be considered. Live loads include the contents of the rooms—movable objects, such as people and furnishings, which any structure is called on to support only at certain times. The various structural members of any building must be made large enough to support these loads when they are present, even though they may not occur often. Dead loads are the weights of the structural parts of the floor. There cannot

TABLE I. ALLOWABLE UNIFORM LOAD FOR
ANGLES IN THOUSANDS OF POUNDS

Shorter Leg Horizontal

Maximum Bending Stress, 16,000 Pounds per Square Inch

SIZE, INCHES	THICK-NESS, INCHES	SAFE LOAD FOR 1-FOOT SPAN	SIZE, INCHES	THICK-NESS, INCHES	SAFE LOAD FOR 1-FOOT SPAN
8 x 8	1⅛	186.99	5 x 4	⅞	53.23
	½	89.28		⅜	24.96
6 x 6	1	91.41	5 x 3½	⅞	52.05
	⅜	37.65		5⁄16	20.69
5 x 5	1	61.87	5 x 3	13⁄16	47.47
	⅜	25.81		5⁄16	20.16
4 x 4	13⁄16	32.11	4½ x 3	13⁄16	38.61
	¼	11.20		5⁄16	16.43
3½ x 3½	13⁄16	24.00	4 x 3½	13⁄16	31.15
	¼	8.43		5⁄16	13.44
3 x 3	⅝	13.87	4 x 3	13⁄16	30.61
	¼	6.19		¼	10.67
2½ x 2½	½	7.79	3½ x 3	13⁄16	23.47
	⅛	2.13		¼	8.32
2 x 2	7⁄16	4.27	3½ x 2½	11⁄16	19.73
	⅛	1.39		¼	8.00
1¾ x 1¾	7⁄16	3.20	3 x 2½	9⁄16	12.27
	⅛	1.07		¼	5.97
1½ x 1½	⅜	2.03	3 x 2	½	10.67
	⅛	0.77		¼	5.76
1¼ x 1¼	5⁄16	1.17	2½ x 2	½	7.47
	⅛	0.52		⅛	2.13
1 x 1	¼	0.60	2½ x 1½	5⁄16	4.69
	⅛	0.33		3⁄16	2.99
8 x 6	1	161.17	2¼ x 1½	½	5.76
	7⁄16	75.41		3⁄16	2.45
8 x 3½	1	146.03	2 x 1½	⅜	3.63
	7⁄16	68.80		⅛	1.39
7 x 3½	1	112.85	2 x 1¼	¼	2.45
	⅜	46.19		3⁄16	1.92
6 x 4	1	85.55	1¾ x 1¼	¼	1.92
	⅜	35.41		⅛	1.00
6 x 3½	1	83.52	1½ x 1¼	5⁄16	1.71
	5⁄16	29.23		3⁄16	1.07

be much uncertainty regarding the weights of these materials since they have all been checked in the laboratory. For residences, then, it is general practice to assume a live load of 40 pounds per square foot of flooring and a dead load of 20 pounds per square foot. The floor load for area $LMNP$ is, therefore, 110×60, or 6,600 pounds.

Partitions for ceilings of usual heights, built of 2 x 4 studs, lath, and plaster can be assumed for rough calculations as weighing about 110 pounds per lineal foot. The partition between rooms 1 and 2 is 10′ long, which makes its weight approximately 1,100 pounds. This, added to the 6,600 pounds (floor load of area $LMNP$) makes a total of 7,700 pounds.

Tables I and II show safe loads for angles when they are used as beams to support floor and partition loads. Note that angles are much stronger when their longest leg or side is in a vertical position. This can be seen by comparing 4″ x 3″ and 3″ x 2″ angles in the two tables. Angles are by far the most adaptable of the many structural shapes available for use in small construction work of all kinds.

TABLE II. ALLOWABLE UNIFORM LOAD FOR ANGLES
WITH LEGS OF UNEQUAL LENGTH IN THOUSANDS OF POUNDS
Longer Leg Horizontal
Maximum Bending Stress, 16,000 Pounds per Square Inch

Size, Inches	Thickness, Inches	Safe Load for 1-Foot Span	Size, Inches	Thickness, Inches	Safe Load for 1-Foot Span
8 x 6	1	95.15	3½ x 3	13/16	17.60
	7/16	45.12		1/4	6.19
8 x 3½	1	32.21	3½ x 2½	11/16	10.56
	7/16	15.57		1/4	4.37
7 x 3½	1	31.57	3 x 2	9/16	8.75
	3/8	13.44		1/4	4.27
6 x 4	1	40.43		1/2	5.01
	3/8	17.07		1/4	2.77
6 x 3½	1	30.93	2½ x 2	1/2	4.91
	5/16	11.09		1/8	1.49
5 x 4	7/8	35.31	2½ x 1½	5/16	1.81
	3/8	16.75		3/16	1.17
5 x 3½	7/8	26.88	2¼ x 1½	1/2	2.77
	5/16	10.88		3/16	1.17
5 x 3	13/16	18.56	2 x 1½	3/8	2.13
	5/16	8.00		1/8	0.80
4½ x 3	13/16	18.24	2 x 1¼	1/4	1.04
	5/16	8.00		3/16	0.80
4 x 3½	13/16	24.53	1¾ x 1¼	1/4	1.01
	5/16	10.67		1/8	0.56
4 x 3	13/16	17.92	1½ x 1¼	5/16	1.17
	1/4	6.40		3/16	0.78

The next step in choosing the proper beam for *GJ* in (A) of Fig. 10 is to select an angle from Tables I or II of such strength that when it is used back to back (see detail in Fig. 10), the 7,700 pound load can be carried safely. From Table I it is seen that a 5″ x 3″ x $^{15}/_{16}$″ angle can support 47,470 pounds over a 1′0″ span. Over a 10′0″ span it can support 47,470 ÷ 10, or 4,747 pounds. The two angles together can support 9,494 pounds on a 10′0″ span. Since this is considerably more than 7,700, these angles will be selected.

In the first floor plan sketch of Fig. 3 there is an opening in the outside brick wall between the living room and the sun porch. This opening extends from the first floor level to the first floor ceiling. A beam must be used as shown in the section view of Fig. 11. The problem is to find the size and required strength of the **I** beam used.

The loads for this beam are calculated in the following manner. Brick weighs 120 pounds per cubic foot. A 9″ brick wall, therefore, weighs 90 pounds per square foot of surface. There are 9′0″ of brick above the beam and the opening is 13′ 9″, or 13.75 feet wide. The area of brick involved, then, is 13.75 feet × 9′, or 123.75 square feet. This area, multiplied by 90, gives a total of 11,138 pounds.

The load from the roof can be assumed to be 35 pounds per square foot. The area of roof which must be supported by the **I** beam is 13.75 feet in width and 14′0″ in length from hip to gable. This is a total area of 193 square feet. This area multiplied by the weight per square foot of roof (35 pounds) gives 6,755 pounds.

The load from the attic floor can be assumed to be 56 pounds per square foot. The nearest other support for attic joists can be assumed as being 16′0″ away. Therefore, the area of floor to be considered in determining the total attic load is 8′ by 13.75 feet. The area is 110 square feet. This area, multiplied by the load per square foot, gives a total load of 6,160 pounds.

The sun parlor roof can be assumed as having a load of 40 pounds per square foot. The nearest support for the rafters is 6′0″ away. For this reason, the area of this roof to be considered is 3′0″ × 13.75 feet, or 41.25 square feet. This area, multiplied by the load it must support, is a total weight of 1,650 pounds.

The second floor load can be assumed to be 60 pounds per square foot. The nearest support for the joists is 16′0″ away. Therefore, the

ELEVATION VIEW

DETAIL SHOWING
HOW JOISTS ARE
HUNG FROM "I" BEAM

WALL SECTION
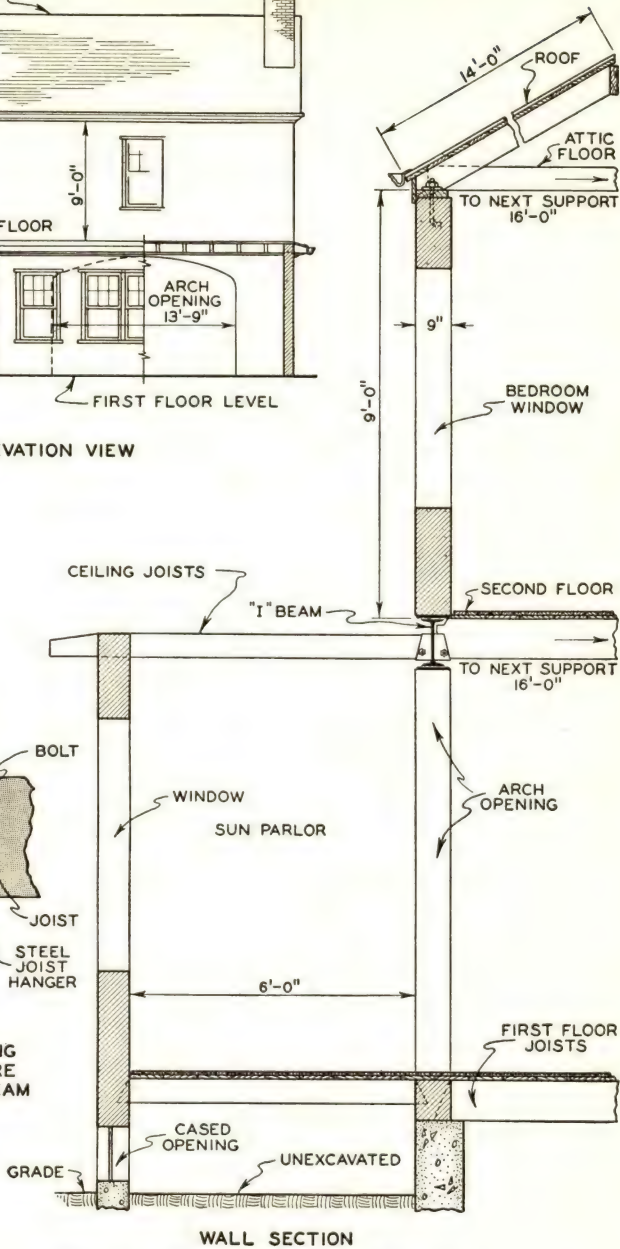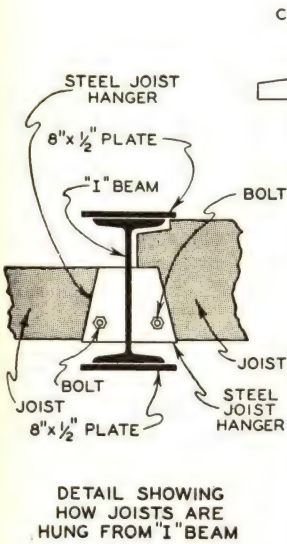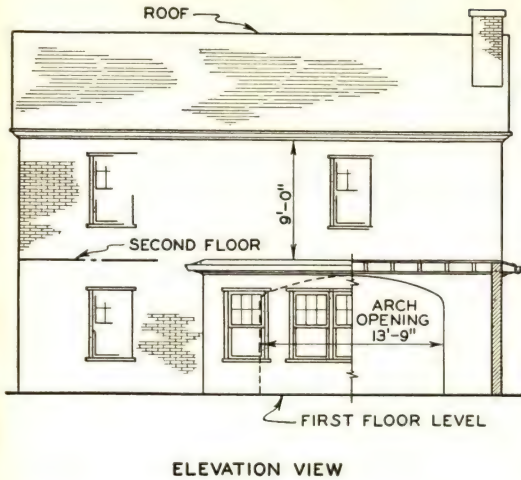
Fig. 11. Selection of I Beam over Outside Wall Opening

area to be considered is 8′0″ × 13.75 feet or 110 square feet. This area, multiplied by the load it must support, is a total weight of 6,600 pounds.

The total load in pounds is therefore:

Brick wall 11,138
Roof 6,755
Attic 6,160
Sun parlor roof............................. 1,640
Second floor 6,600
  Total live and dead load....................32,293

Tables III and IV show safe loads for **I** beams of various spans and shapes in thousands of pounds. In Table IV opposite the span of 14′ and under the column headed 12-inch, 40.8 pounds, will be found the figure 34.2. This means that an **I** beam 12″ in depth and weighing

TABLE III. ALLOWABLE UNIFORM LOAD ON STEEL **I** BEAMS
IN THOUSANDS OF POUNDS*

Maximum Bending Stress, 16,000 Pounds per Square Inch

| Span in Feet | Depth and Weight of Sections | | | | | | | | | | | | Coefficient of Deflection |
| | 10-Inch | | 9-Inch | | 8-Inch | | 7-Inch | 6-Inch | 5-Inch | 4-Inch | 3-Inch | |
	40 Lbs.	25.4 Lbs.	35 Lbs.	21.8 Lbs.	25.5 Lbs.	18.4 Lbs.	15.3 Lbs.	12.5 Lbs.	10 Lbs.	7.7 Lbs.	5.7 Lbs.	
1	....	....	....	....	....	....	....	....	....	....	10.2	0.02
2	149.8	....	131.8	....	86.6	....	....	27.6	21.0	15.2	8.8	0.07
3	112.8	....	88.3	52.2	60.8	43.2	35.0	25.8	17.2	10.6	5.9	0.15
4	84.6	62.0	66.2	50.3	45.6	37.9	27.6	19.4	12.9	8.0	4.4	0.27
5	67.7	52.1	53.0	40.3	36.5	30.3	22.1	15.5	10.3	6.4	3.5	0.41
6	56.4	43.4	44.2	33.6	30.4	25.3	18.4	12.9	8.6	5.3	2.9	0.60
7	48.4	37.2	37.9	28.8	26.1	21.7	15.8	11.1	7.4	4.5	....	0.81
	....	....	....	....	....	....	....	....	....	....	2.5	....
8	42.3	32.6	33.1	25.2	22.8	19.0	13.8	9.7	6.4	4.0	2.2	1.06
9	37.6	28.9	29.4	22.4	20.3	16.9	12.3	8.6	5.7	3.5	....	1.34
10	33.9	26.0	26.5	20.1	18.2	15.2	11.0	7.7	5.2	3.2	....	1.66
11	30.8	23.7	24.1	18.3	16.6	13.8	10.0	7.0	4.7	....	....	2.00
12	28.2	21.7	22.1	16.8	15.2	12.6	9.2	6.5	4.3	....	....	2.38
13	26.0	20.0	20.4	15.5	14.0	11.7	8.5	6.0	....	....	....	2.80
14	24.2	18.6	18.9	14.4	13.0	10.8	7.9	5.5	....	....	....	3.24
15	22.6	17.4	17.7	13.4	12.2	10.1	7.4	....	....	....	....	3.72
16	21.2	16.3	16.6	12.6	11.4	9.5	6.9	....	....	....	....	4.24
17	19.9	15.3	15.6	11.8	10.7	8.9	....	....	....	....	....	4.78
18	18.8	14.5	14.7	11.2	10.1	8.4	....	....	....	....	....	5.36
19	17.8	13.7	13.9	10.6	....	....	....	....	....	....	....	5.98
20	16.9	13.0	13.3	10.1	....	....	....	....	....	....	....	6.62
21	16.1	12.4	....	....	....	....	....	....	....	....	....	7.30
22	15.4	11.8	....	....	....	....	....	....	....	....	....	8.01

*Loads above upper horizontal lines will produce maximum allowable shear in webs. Loads below lower horizontal lines will produce excessive deflections.

Table IV. Allowable Uniform Load on Steel I Beams in Thousands of Pounds*

Maximum Bending Stress, 16,000 Pounds per Square Inch

Span in Feet	Depth and Weight of Sections												Coefficient of Deflection
	27-Inch	24-Inch		20-Inch		18-Inch		15-Inch		12-Inch			
	90 Lbs.	115 Lbs.	79.9 Lbs.	100 Lbs.	65.4 Lbs.	90 Lbs.	54.7 Lbs.	75 Lbs.	42.9 Lbs.	55 Lbs.	40.8 Lbs.	31.8 Lbs.	
	.....	.....	.....	.....	.....	.....	.....	.....	.....	197.0	.....	....	.....
3	.....	.....	.....	.....	.....	.....	.....	264.6	.....	190.2	.....	....	0.15
4	.....	.....	.....	353.6	.....	.....	.....	245.8	.....	142.7	110.4	84.0	0.27
5	.....	.....	.....	353.2	.....	290.5	165.6	196.6	123.0	114.1	95.6	76.7	0.41
6	.....	.....	.....	294.3	200.0	249.0	157.1	163.8	104.7	95.1	79.7	63.9	0.60
7	.....	360.0	240.0	252.3	178.2	213.4	134.7	140.4	89.8	81.5	68.3	54.8	0.81
8	283.0	328.4	231.9	220.7	155.9	186.7	117.9	122.9	78.5	71.3	59.8	48.0	1.06
9	259.3	291.9	206.1	196.2	138.6	166.0	104.8	109.2	69.8	63.4	53.1	42.6	1.34
10	233.4	262.7	185.5	176.6	124.7	149.4	94.3	98.3	62.8	57.1	47.8	38.4	1.66
11	212.2	238.8	168.7	160.5	113.4	135.8	85.7	89.4	57.1	51.9	43.5	34.9	2.00
12	194.5	218.9	154.6	147.2	104.0	124.5	78.6	81.9	52.4	47.6	39.8	32.0	2.38
13	179.5	202.1	142.7	135.8	96.0	114.9	72.5	75.6	48.3	43.9	36.8	29.5	2.80
14	166.7	187.7	132.5	126.1	89.1	106.7	67.3	70.2	44.9	40.8	34.2	27.4	3.24
15	156.6	175.1	123.7	117.7	83.2	99.6	62.9	65.5	41.9	38.0	31.9	25.6	3.72
16	145.9	164.2	116.0	110.4	78.0	93.4	58.9	61.4	39.3	35.7	29.9	24.0	4.24
17	137.3	154.5	109.1	103.9	73.4	87.9	55.5	57.8	37.0	33.6	28.1	22.6	4.78
18	129.7	146.0	103.1	98.1	69.3	83.0	52.4	54.6	34.9	31.7	26.6	21.3	5.36
19	122.8	138.3	97.6	92.9	65.7	78.6	49.6	51.7	33.1	30.0	25.2	20.2	5.98
20	116.7	131.4	92.8	88.3	62.4	74.7	47.1	49.2	31.4	28.5	23.9	19.2	6.62
21	111.1	125.1	88.3	84.1	59.4	71.1	44.9	46.8	29.9	27.2	22.8	18.3	7.30
22	106.1	119.4	84.3	80.3	56.7	67.9	42.9	44.7	28.6	25.9	21.7	17.4	8.01
23	101.5	114.2	80.7	76.8	54.2	64.9	41.0	42.7	27.3	24.8	20.8	16.7	8.76
24	97.3	109.5	77.3	73.6	52.0	62.2	39.3	41.0	26.2	23.8	19.9	16.0	9.53
25	93.4	105.1	74.2	70.6	49.9	59.8	37.7	39.3	25.1	22.8	19.1	15.3	10.35
26	89.8	101.0	71.4	67.9	48.0	57.5	36.3	37.8	24.2	21.9	18.4	14.8	11.19
27	86.4	97.3	68.7	65.4	46.2	55.3	34.9	36.4	23.8	.....	.....	....	12.07
28	83.4	93.8	66.3	63.1	44.6	53.3	33.7	35.1	22.4	.....	.....	....	12.98
29	80.5	90.6	64.0	60.9	43.0	51.5	32.5	33.9	21.7	.....	.....	....	13.92
30	77.8	87.6	61.8	58.9	41.6	49.8	31.4	32.8	20.9	.....	.....	....	14.90
31	75.3	84.7	59.8	57.0	40.2	48.2	30.4	31.7	20.3	.....	.....	....	15.91
32	72.9	82.1	58.0	55.2	39.0	46.7	29.5	30.7	19.6	.....	.....	....	16.95
33	70.7	79.6	56.2	53.5	37.8	45.3	28.6	.....	.....	.....	.....	....	18.03
34	68.6	77.3	54.6	51.9	36.7	43.9	27.7	.....	.....	.....	.....	....	19.13
35	66.7	75.1	53.0	50.5	35.6	42.7	26.9	.....	.....	.....	.....	....	20.28
36	64.8	73.0	51.5	49.1	34.7	41.5	26.2	.....	.....	.....	.....	....	21.45
37	63.1	71.0	50.1	47.7	33.7	40.4	25.5	.....	.....	.....	.....	....	22.66
38	61.4	69.1	48.8	46.5	32.8	39.3	24.8	.....	.....	.....	.....	....	23.90
39	59.8	67.4	47.6	45.3	32.0	.....	.....	.....	.....	.....	.....	....	25.18
40	58.4	65.7	46.4	44.1	31.2	.....	.....	.....	.....	.....	.....	....	26.48
41	56.9	64.1	45.3	43.1	30.4	.....	.....	.....	.....	.....	.....	....	27.82
42	55.6	62.6	44.2	42.0	29.7	.....	.....	.....	.....	.....	.....	....	29.20
43	54.3	61.1	43.1	.....	.....	.....	.....	.....	.....	.....	.....	....	30.60
44	53.0	59.7	42.2	.....	.....	.....	.....	.....	.....	.....	.....	....	32.04
45	51.9	58.4	41.2	.....	.....	.....	.....	.....	.....	.....	.....	....	33.52
46	50.7	57.1	40.3	.....	.....	.....	.....	.....	.....	.....	.....	....	35.02
47	49.7	55.9	39.5	.....	.....	.....	.....	.....	.....	.....	.....	....	36.56
48	48.6	54.7	38.7	.....	.....	.....	.....	.....	.....	.....	.....	....	38.14
49	47.6	53.6	37.9	.....	.....	.....	.....	.....	.....	.....	.....	....	39.74
50	46.7	52.5	37.1	.....	.....	.....	.....	.....	.....	.....	.....	....	41.38

*Loads above upper horizontal lines will produce maximum allowable shear in webs. Loads below lower horizontal lines will produce excessive deflections.

40.8 per foot will safely carry a load of 34,200 pounds over a span of 14 feet. Since this beam weighs 40.8 pounds per foot, its total weight will be 561 pounds. This, added to the weight the beam must support (32,293) makes a total of 32,854 pounds. Therefore, the beam selected is safe for the loads it must carry.

In order to allow ample bearing surface at each end, the length of the beam when placed in the structure would be 16 feet.

Fig. 12 shows a rough detail drawing for a dairy barn such as was shown in Fig. 4. The main beam at X in Fig. 4 is the same beam as is
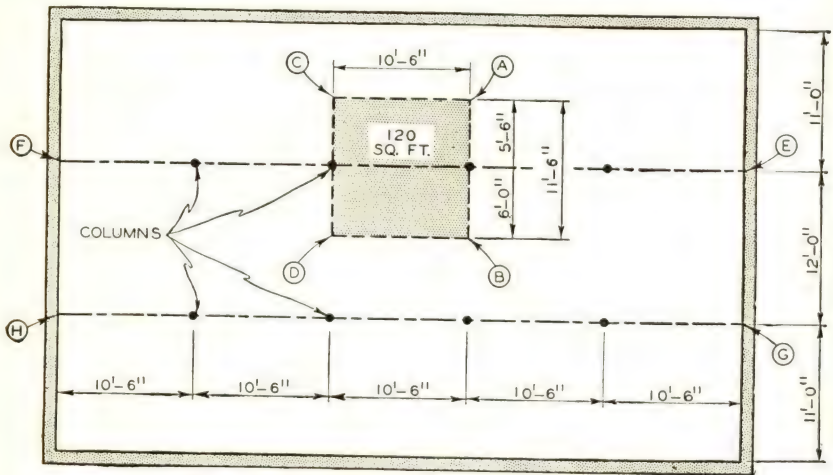
Fig. 12. Selection of I Beams for Haymow Floor

indicated between the columns at FE and HG in Fig. 12. In order to become familiar with the selection of the proper beam to be used in a structure of the type shown in Figs. 4 and 12, assume it is necessary to provide the beam for one section of the series of beams between F and E.

It will be noted that between F and E in Fig. 12 there are five separate sections or beams. Each of these beams has its own load. In other words, the distance FE is not all one beam. Each of the five beams is supported separately and each carries its share of the total load. To all intents and purposes, each section is an individual beam.

Note the shaded area $CDAB$ in Fig. 12. This is the load area for one of the beams. It can be seen that the load area is half the dis-

tance to the nearest support on both sides. This area is 11′6″ by 10′6″, or 120¾ square feet. For ease in calculations, this can be assumed to be an even 120 square feet.

If chopped hay or fodder is stored to a depth of 17′0″ on this floor, the load, including the floor dead load, will be about 200 pounds per square foot. Shelled corn 4′0″ deep would give about the same load. Long hay to a depth of 20′0″ would make a floor load of about 100 pounds per square foot. In determining the beam to be used for this particular structure, the maximum floor load of 200 pounds will be assumed. The total uniform floor load is therefore 120 × 200, or 24,000 pounds.

Referring to Table III it can be seen that a 9″, 35-pound **I** beam will carry 24,100 pounds safely over an 11′ span. A 10″, 40-pound **I** beam will support 30,800 pounds over the span. Since the 35-pound beam does not have a very great safety factor, the 40-pound beam is selected for the job.

All other beams for both *FE* and *HG* in Fig. 12 have approximately the same loading. The lighter beams used as joists (see Fig. 4) are selected as were the beams on a basis of the expected load area for each beam.

The **I** beams discussed in Figs. 6 and 7 are selected using the same procedures just explained. Recommended live and dead loads and combinations of them can be secured from the city building codes, from building material yards, and from agricultural stations or offices at state colleges. Some building yards also offer design service.

The method of beam selection explained here is commonly used by architects, engineers, and any other person interested in making the proper choice of beams for building purposes. In addition to the tables for the allowable uniform load on steel beams presented in this chapter, the American Institute of Steel Construction publishes "safe load tables" for all steel shapes.

In Tables III and IV, the safe loads for steel beams are based on a maximum allowable bending stress of 16,000 pounds per square inch. Most authorities consider it a safe practice to use a bending stress of 18,000 and even 20,000 pounds. If the 18,000-pound figure is used, the loads in the tables may be increased by ⅛. If the 20,000-pound figure is used, the loads may be increased by ¼. This allowable increase is

due to the improved quality of the steel going into beams since most of the load tables were compiled.

Beam tables instead of giving "safe loads," as in Tables III and IV, sometimes give the moment of inertia of the beam. The symbol for this term is the letter I. When using such a table, it is necessary to calculate the moment of inertia and then select a beam having an equal or greater value. There is a simple way of calculating the moment of inertia using the following formula:

$$I = \frac{W \times (\text{span in feet})^2}{25,777}$$

I = the moment of inertia

W = total uniform load

In order to understand the application of this formula, assume an I beam 12′ 0″ long supports a uniform load of 20,000 pounds. The problem is to select the size of beam required for the job.

Substituting values for letters in the formula, we have

$$I = \frac{20,000 \times 12^2}{25,777}$$

$$I = \frac{20,000 \times 144}{25,777}$$

$$I = \frac{2,880,000}{25,777}$$

$$I = 111.7$$

Table V shows that a 10″, 35 pound I beam has a value of 111. Therefore, the 10″ beam is selected as being adequate for the purpose. When using Table V, be careful to select values for the proper axis. When an I beam stands vertically as shown in Table V, use axis 1-1.

Steel beams of all kinds should be selected and their use planned according to the standard lengths available at the various lumber yards or other sources of supply. It is wise to determine what lengths suppliers have in stock and to use such lengths without requiring any cutting to be done. Beams of any length can be made to order by manufacturers but where a small number of them are required, it is much more economical to use such lengths as may be quickly obtainable. It is not always possible to secure the exact lengths desired as

TABLE V. MOMENT OF INERTIA FOR STEEL I BEAMS

DEPTH OF BEAM	WEIGHT PER FOOT	AREA OF SECTION	WIDTH OF FLANGE	THICK-NESS OF WEB	AXIS 1-1 I	AXIS 2-2 I
In.	Lbs.	In.	In.	In.	In.	In.
	55.0	16.04	5.600	0.810	319.3	17.3
12	50.0	14.57	5.477	0.687	301.6	16.0
	45.0	13.10	5.355	0.565	284.1	14.8
	40.8	11.84	5.250	0.460	268.9	13.8
12	35.0	10.20	5.078	0.428	227.0	10.0
	31.8	9.26	5.000	0.350	215.8	9.5
12	27.9	8.15	6.000	0.284	199.4	12.6
	40.0	11.69	5.091	0.741	158.0	9.4
10	35.0	10.22	4.944	0.594	145.8	8.5
	30.0	8.75	4.797	0.447	133.5	7.6
	25.4	7.38	4.660	0.310	122.1	6.9
10	22.4	6.54	5.500	0.252	113.6	9.0
	35.0	10.22	4.764	0.724	111.3	7.3
9	30.0	8.76	4.601	0.561	101.4	6.4
	25.0	7.28	4.437	0.397	91.4	5.6
	21.8	6.32	4.330	0.290	84.9	5.2
	25.5	7.43	4.262	0.532	68.1	4.7
8	23.0	6.71	4.171	0.441	64.2	4.4
	20.5	5.97	4.079	0.349	60.2	4.0
	18.4	5.34	4.000	0.270	56.9	3.8
8	17.5	5.13	5.000	0.220	58.4	6.2
	20.0	5.83	3.860	0.450	41.9	3.1
7	17.5	5.09	3.755	0.345	38.9	2.9
	15.3	4.43	3.660	0.250	36.2	2.7
	17.25	5.02	3.565	0.465	26.0	2.3
6	14.75	4.29	3.443	0.343	23.8	2.1
	12.5	3.61	3.330	0.230	21.8	1.8
	14.75	4.29	3.284	0.494	15.0	1.7
5	12.25	3.56	3.137	0.347	13.5	1.4
	10.0	2.87	3.000	0.210	12.1	1.2
	10.5	3.05	2.870	0.400	7.1	1.0
4	9.5	2.76	2.796	0.326	6.7	0.91
	8.5	2.46	2.723	0.253	6.3	0.83
	7.7	2.21	2.660	0.190	6.0	0.77
	7.5	2.17	2.509	0.349	2.9	0.59
3	6.5	1.88	2.411	0.251	2.7	0.51
	5.7	1.64	2.330	0.170	2.5	0.46

for example, in Figs. 3 and 4. For this reason, either the planning must be changed to suit available lengths or the available lengths will have to be cut to the proper size. Knowing in advance what lengths are available, the designer or architect can make his plans accordingly and save the expense of cutting beams to a special length. Generally, suppliers will be glad to help in this planning.

Selection of Reinforced Concrete Beams. The design and selection of reinforced concrete beams is an extremely technical phase of construction engineering and for that reason is not included in the scope of this book. If the use of reinforced concrete beams in a structure is

SECTION VIEW

FIRST FLOOR   SECOND FLOOR
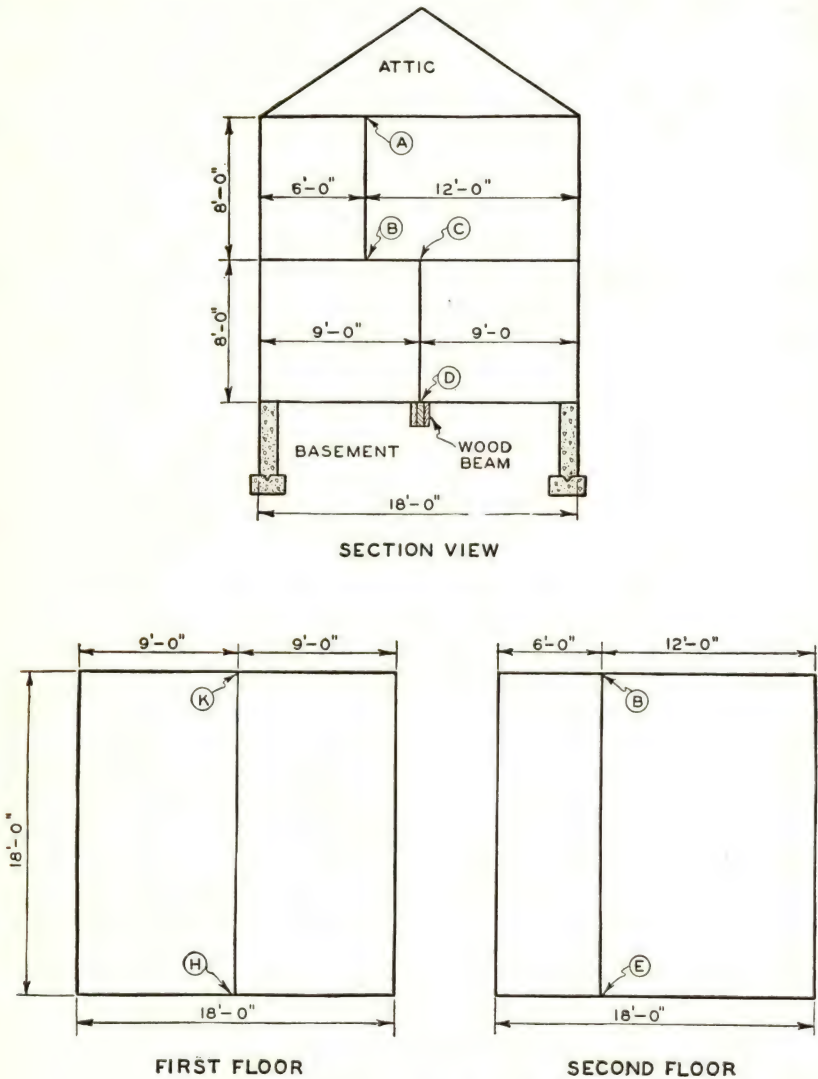
Fig. 13. Selection of Wood Beams for Residence

desirable, the services of a competent structural engineer should be obtained.

Selection of Wood Beams. The selection of wood beams, sometimes called girders, is not greatly different from the procedures described for steel beams. For the most part, wood beams are shorter than beams of steel because wood is not as strong or as stiff as steel. For this reason, where wood beams are used, more column supports are necessary.

Fig. 13 shows rough sketches of a residence or similar structure. The sketch is more a diagram than a plan and is presented merely as an aid to the understanding of the problems involved in the proper selection of wood beams. The beam under discussion is in the basement of the section view. It must support loads from the structure which are not supported by the outside walls. The problem is to select the correct beam as well as the proper number of beam supports or columns.

As in the case of steel beams, the calculation of loads must start at the top of the structure. Since the roof loads are supported by the side walls, they need not be considered as a load on the beam.

The attic floor is partly supported by bearing partition AB. This partition must support all floor loads from A halfway to the next support (the walls) on either side. In other words, partition AB supports a floor area 3′ 0″ plus 6′ 0″ or 9′ 0″ wide and 18′ 0″ long, making an area of 162 square feet. If only the dead load of 40 pounds per square foot of attic floor is considered, the total load is 162 × 40, or 6,480 pounds. Bearing partition AB transmits this 6,480-pound load to the second floor joists.

The second floor is partly supported by bearing partition CD. This partition must support all second floor loads from C halfway to the next supports on either side. In other words, partition CD supports a floor area 4′ 6″ plus 4′ 6″ or 9′ 0″ wide and 18′ 0″ long. This makes an area of 162 square feet. If the combined live and dead loads are assumed as 60 pounds per square foot,[1] then the total load is 162 × 60, or 9,720 pounds.

The weight of partition AB must be included in the total load on

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[1] For granaries or other farm storage uses, the floor loads per square foot must be carefully considered.

the beam. An extra allowance of 12 pounds per square foot of floor area involved is added to the total weight or load the beam must support. Thus, 162 × 12, or 1,944 pounds, is added to the other loads. This method of determining the weight of partitions is not quite accurate when the partition is not directly over the beam that must support it but it gives results which compare favorably with those obtained by a more accurate but much more complicated method.

The first floor area under consideration is the same as the second floor, and if the same live and dead loads are assumed, the total load of the first floor will be 9,720 pounds.

TABLE VI. SAFE LOADS FOR STUD PARTITIONS*
BASED ON STUDS BEING BRIDGED AT CENTER

NOMINAL SIZE	ACTUAL SIZE	DISTANCE ON CENTERS, INCHES	HEIGHT, FEET	PER LINEAL FOOT OF PARTITION		
				Safe Load, Pounds	Weight, Pounds	Board Feet
2 x 4.......	$1\frac{5}{8}$ x $3\frac{5}{8}$	12	8	3723	16.30	6.66
		12	10	3180	19.56	8.00
		12	12	2631	22.82	9.33
		16	8	2793	13.04	5.33
		16	10	2385	15.50	6.33
		16	12	1974	18.00	7.33
2 x 6.......	$1\frac{5}{8}$ x $5\frac{5}{8}$	12	8	5767	25.30	10.00
		12	10	4926	30.56	12.00
		12	12	4076	35.42	14.00
		16	8	4326	20.24	8.00
		16	10	3699	24.03	9.50
		16	12	3057	27.83	11.00

*Weight and strength based on actual size. Board measure based on nominal size. Add weight of plaster or ceiling. Single plate top and bottom, same size as studs, included.
Courtesy of Southern Pine Association

The weight of the partition *CD* also must be added to the total beam load. When the partition is directly over the beam as shown in Fig. 13, the method of allowing for its weight is as follows: The actual weight for partition studs per lineal foot of partitions of various heights is given in Table VI. For an 8′ 0″ partition built of 2 x 4 studs set on 16″ centers, the weight is 13.04 pounds per lineal foot. To this must be added approximately 12 pounds per square foot of partition area to allow for the weight of the lath and plaster or other wall covering. For a partition 8′ 0″ high, this would be 8 × 12 pounds, or 96 pounds per lineal foot of partition. This weight, added to the weight of the studding, is 109 pounds. For ease in calculations, this may be assumed to be an even 100 pounds. Since partition *CD* is 18′ 0″ long, its weight is 100 × 18, or 1,800 pounds.

The total load in pounds is therefore:

Attic floor	6,480
Second floor	9,720
Second floor partition......................	1,944
First floor	9,720
First floor partition........................	1,800
Total live and dead load....................	29,664

It should be clearly understood that the attic floor load is transmitted to the second floor joists by partition *AB* and that partition *CD* carries not only the second floor load but the load coming from the attic through partition *AB* as well. Joists are designed or selected using much the same procedure as was explained for wood and steel beams.[2]

Note Table VII which shows safe loads for various sizes of solid and built-up (spiking method) wood beams. It can be seen that even an 8 x 10 solid wood beam cannot safely carry 29,664 pounds over an

TABLE VII. SAFE LOADS FOR WOOD BEAMS

SIZE, INCHES	SAFE LOAD IN LBS. FOR SPANS FROM 6 TO 10 FT.				
	6 Ft.	7 Ft.	8 Ft.	9 Ft.	10 Ft.
6 x 8 solid...............	6,874	5,891	5,148	4,584	4,124
6 x 8 built up............	6,090	4,560	4,220	4,062	3,654
6 x 10 solid...............	11,029	9,451	8,260	7,355	6,618
6 x 10 built up............	9,774	8,376	7,320	6,519	5,865
8 x 8 solid...............	9,373	8,033	7,020	6,251	5,624
8 x 8 built up............	8,120	6,960	6,080	5,416	4,872
8 x 10 solid...............	15,038	12,887	11,262	10,027	9,023
8 x 10 built up............	13,032	11,168	9,760	8,692	7,820

Courtesy of Weyerhaeuser Forest Products Company

18' 0" span. Note (A) in Fig. 14. If one support at the middle of the span were used, the beam would be divided into two spans each 9' 0" in length. Each span would be required to support one half of 29,664, or 14,832 pounds. This load is also too great for the 8 x 10 wood beam. The
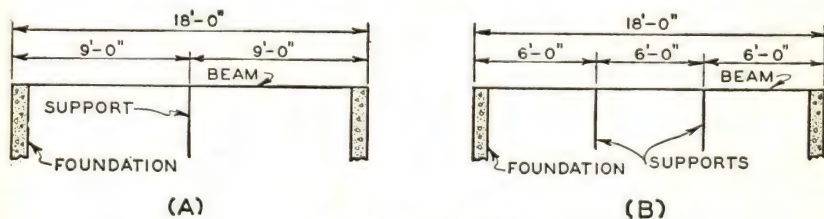
Fig. 14. Beam Spans

[2] Complete explanations relative to joist spacing and sizing can be found in *How to Plan a House* and *How to Remodel a House*, published by the American Technical Society.

use of two supports dividing the beam into three spans of 6′ 0″ results in spreading the 29,664-pound load so that each of the three beams will be supporting a third of the load, or 9,888 pounds. According to Table VII, it will be possible to use a built-up beam which is cheaper than the solid beam. It can readily be seen that by increasing the number of supports, thus reducing the length and load per span, it is possible to use wood beams of smaller size.

The design and selection of compound beams such as shown in (C) and (D) of Fig. 9 require more complicated mathematical treatment and therefore should be the work of architects or structural engineers.

HOW TO PLACE BEAMS

There are many satisfactory ways of placing beams in their proper positions. Placing depends on an almost unlimited number of conditions relative to the buildings. In the following pages, typical examples are explained and illustrated. These examples are the ones most often encountered in average construction work on residences, farm buildings, apartments, and similar structures.

Placing Steel Beams. Suppose that the steel **I** beams from E to F in Fig. 3 are to be supported at G and H by Lally columns and that the ends of the beams at E and F are to be supported by the foundations. It is necessary that the **I** beams be put in place and secured.

Beams are usually quite heavy and often require some mechanical means of being hoisted into place. Most contractors are equipped with a small derrick and hand windlass or at least a block and tackle with which the beams may be raised. Extreme care should be observed when handling beams, for a falling beam may injure workmen in addition to bending the beam.

The beam ends rest on a plate or enlarged portion of the Lally column as shown in Figs. 5 and 15. There are four holes provided in the column top plate. The beam ends are bolted to the top plate through its holes and through holes drilled in the beam by the supplier according to the builder's specifications. The two beam ends should be about half an inch apart after being bolted down. Another plate sometimes is bolted to the webs of the beams as shown in Fig. 15. In small buildings where beams are used as shown in Fig. 4, web bolting is not necessary although it does make the beam assemblies stiffer.

The ends of beams supported by foundations as at E and F in Fig. 3 may bear right in the concrete or may be supported by the brickwork directly above the foundation, depending upon the depth of the basement below grade line. In (A) of Fig. 16 is shown a situa-

tion where the first floor level is considerably above grade line. Shallow excavations of this kind occur frequently on hillsides or in wet ground. In this case, in order to provide the proper distance, C, between the basement and the first floor, the end of the beam at E must be supported by the brickwork. The beam generally extends into an 8″ wall for about four inches. Where the load on the beam is considered heavy and the span about double that of EG in Fig. 3, a steel plate may be put under the end of the beam as at E in Fig. 16 and a 4″ brick pilaster constructed against the foundation and brickwork from the beam down to the footing.

Fig. 15. Support of I Beam Ends by Lally Columns

Such pilasters are usually from 8″ to 12″ wide. The brickwork is built around the beam end.

In (B) of Fig. 16 is shown a situation in which the required distance between the first floor level and basement is entirely below grade. In this case the beam end has at least 4″ of bearing and possibly more. In 8″ foundations, a 4″ brick pilaster is laid as was just explained. The recess in the concrete for the beam end is provided at the time the foundations are built. If the foundation is of brick, the 4″ pilasters and steel plate will be required.

If the foundation is laid up using concrete blocks, the holes in

the blocks directly under the bearing surface of the beam are filled with concrete as the courses are laid. This insures a solid, column-like bearing for the beam. If beam loads are very heavy, a pilaster is necessary here as well as for brick foundations.
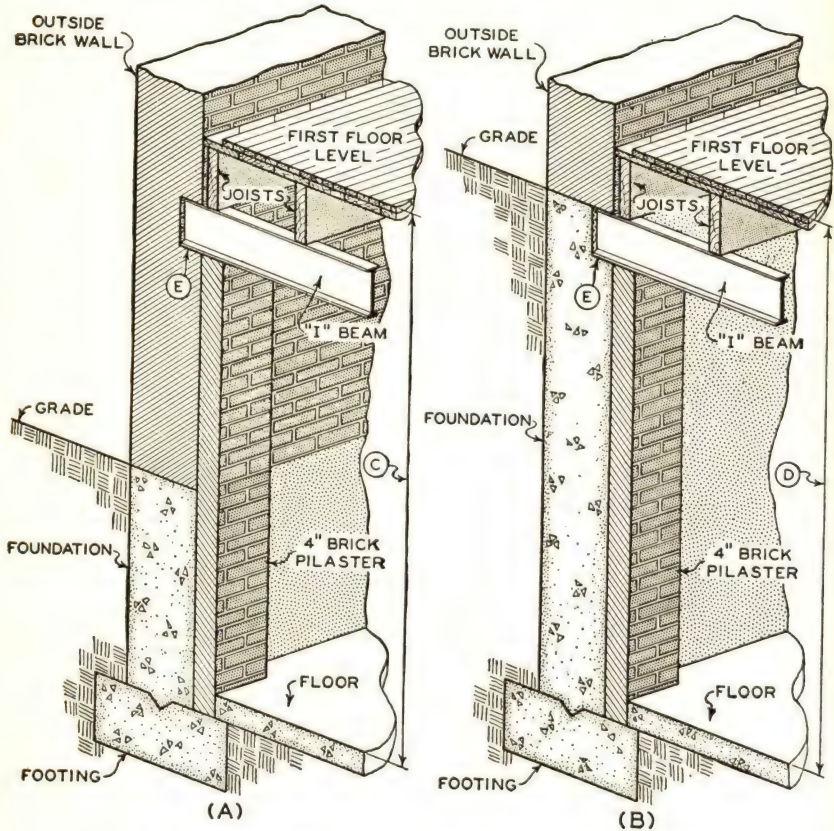
Fig. 16. Beam Support in Brick Wall and Concrete Foundation

The setting of the beam shown at *AB* in Fig. 3 and in Fig. 11 is not difficult. The beam that was selected was 16′ 0″ but the opening it was to span was 13′ 9″ wide. This leaves slightly more than 12″ of bearing for the beam on either side of the opening. The brickwork under the beam should be smooth and a bed of freshly spread mortar placed just before the beam is set. The plate over the beam for the purpose of supporting 8″ brickwork must be the same length as the

beam. It can be bolted to the beam or the weight of the brickwork can be depended upon to keep it in place.

Steel plates, steel **I** beams, and reinforced concrete lintels can be used under the ends of beams carrying heavy loads as a means of distributing the load from the beam over a greater portion of the wall. An example of this practice is illustrated in Fig. 7. Steel **I** beams 2′ 0″ long and steel plates are used at the bearing ends of the beams. When such auxiliary bearing surface is provided, the load is spread over an additional area of from 12″ to 24″ of wall.

When brick columns instead of Lally columns are used to support **I** beams, a steel plate or short section of the **I** beam should be embedded in mortar at the top of the column as a means of obtaining better distribution of the load throughout the column. The beam ends should be securely bolted to the steel plate or **I** beam auxiliary bearing surface. When concrete block columns are used, the cells of the blocks should be filled with concrete and the column topped off with a 4″ concrete slab or a steel plate. In both cases the beam ends should be bolted fast. If the concrete topping is used, anchor bolts are embedded in the concrete just after it is placed.

When light **I** beams are used to help support a concrete floor or roof as shown in (B) of Fig. 5, they should have at least 4″ of bearing in the wall and should be attached to the larger **I** beams with steel angles and rivets as shown in Fig. 17. Steel suppliers
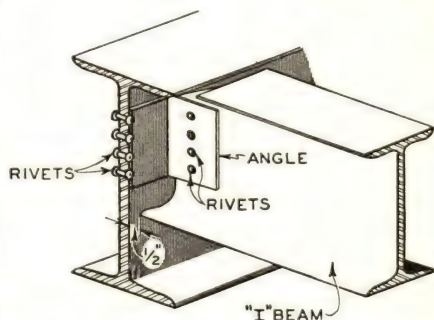
Fig. 17. Method of Joining **I** Beams of Different Sizes

will furnish information and prepare all such connections as required.

Placing Reinforced Concrete Beams. Since almost all concrete beams are an integral part of the floor which they support, it is important that the stirrups and other reinforcing bars have been placed properly within the forms before the concrete is poured. Care must be taken to wire the forms and reinforcing rods in place so that the bottom or horizontal bars and stirrups are the required distances from the outside edges of the beam.

The concrete mix recommended for work of this nature is a ratio of 1:2¼:3. Five gallons of water per sack of cement should be used when the sand is of average wetness. The concrete should flow easily around the reinforcing bars and should be carefully spaded around the edges of the forms. If possible, the concrete for all beams, flooring, etc., should be poured in one continuous operation. This is necessary in order to obtain the maximum strength and stiffness of the concrete, qualities which are greatest when all pouring is done at one time. Sufficient help and a long day generally will make possible the one-operation pouring of the concrete for beams and floors in ordinary
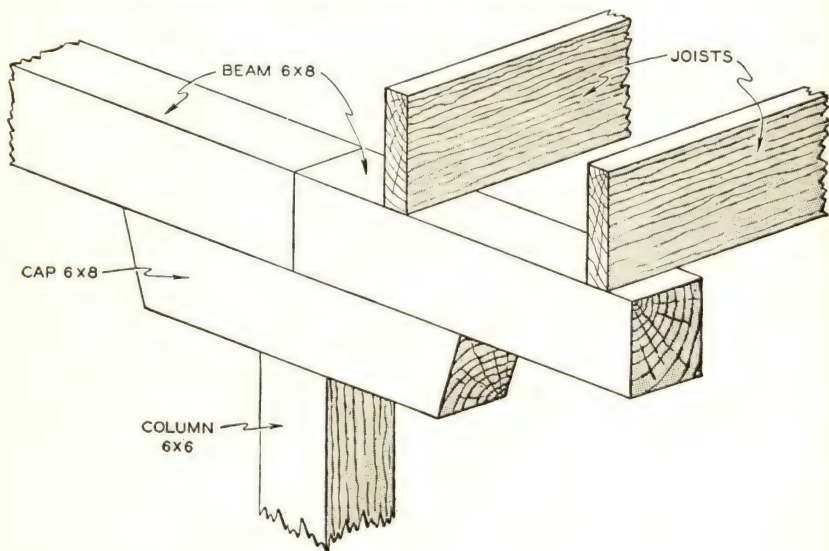
Fig. 18. Support of Wood Beams by Wood Columns

residence work. If complete pouring cannot be done in one day, a structural engineer should be consulted. Reinforced concrete work must be done to perfection in order to avoid inferior work.

In warm weather, forms can be removed safely three or four days after pouring. In cold weather, as much as two weeks' time should be allowed before stripping the forms. Where reinforced concrete beams and floors have been built similar to those shown in (C) of Fig. 5, no loads should be put on the floor for at least two weeks and the full load should not be put on until 28 days after pouring unless high early-

strength cement was used, in which case they may be loaded earlier.

Placing Wood Beams. Since almost all built-up wood beams such as shown in (A) and (B) of Fig. 9 are built on the job, a few words concerning their construction is necessary before their placement in buildings is considered. Note the beam in (A) of Fig. 9. For beams of this nature composed of two pieces, ten-penny (10d) nails should be used. Those beams built up from three pieces of lumber should be fastened with twenty-penny (20d) nails. Nails should be spaced 24" apart and staggered along the top and bottom edges of the beam so that no two nails are closer together than 12 inches. When more than three pieces are required for a built-up beam, the extra pieces are nailed
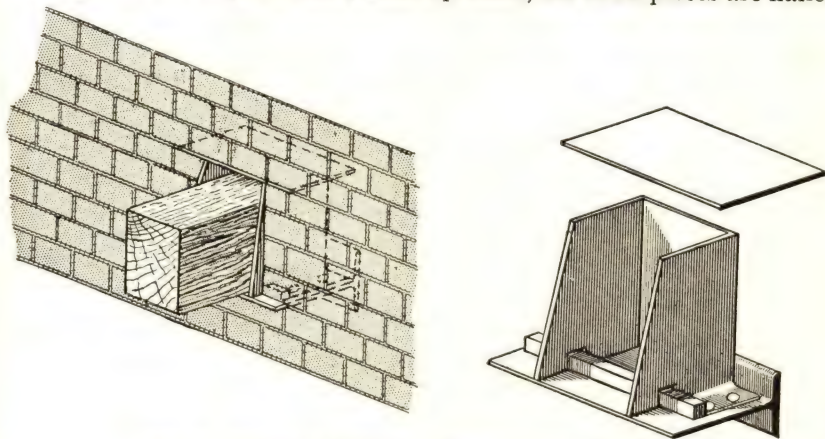
Fig. 19. Method of Supporting Wood Beam in a Brick Wall

to each side of the beam with twenty-penny (20d) nails, spaced in the same way as for thinner beams but staggered with the other nails.

The ends of both solid and built-up wood beams are supported by wood columns as shown in Fig. 18. The cap should be at least three times as long as the column is wide. The ends of the beams should meet over the center of the column. The cap should be toenailed to the column with three spikes on either side. These spikes should extend well into the column. The beam ends should be toenailed to the cap, using four spikes to a side.

Wood beams such as found in Fig. 13 and 14 should be built up and supported over wood columns as was just explained. Wood beams are supported in foundations or outside walls in much the same man-

ner as was described in Fig. 16. Where wood beams are supported by a brick wall, a steel wall box such as shown in Fig. 19 is often used.

Note: Self-check and review questions on the preceding material are included at the end of the chapter. Should you care to examine yourself on the subject matter just covered, turn to them now. Otherwise, continue with your reading.

THEORY OF LINTELS

When the outside walls of houses, barns, and other structures are built of masonry veneer or of solid masonry, there must be members resembling beams for the purpose of supporting the masonry work over the openings for windows and doors. Occasionally, the masonry work over such openings is made to support itself through forming an arch, but generally, a level window or door head is desired.
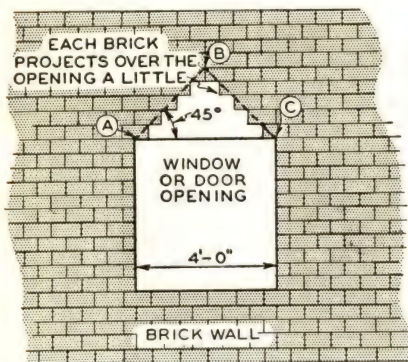
Fig. 20. Window or Door Opening in a Brick Wall and Spandrel

Fig. 20 shows an opening in a brick wall which could be for either a window or a door. In this typical example, support is needed for the brickwork over the opening between *AC*. Supports or beams used for such purposes are called lintels.

Contrary to what might be expected, the lintel for a lone window in a brick wall must support relatively little of the brickwork directly above the window opening. Actually, only that portion of the brickwork within the isosceles triangle *ABC* requires support. This is explained as follows: If brickwork or any other kind of masonry used in walls is well laid and carefully bonded with a good mortar and thin joints, it will have what is known as a corbeling property. As can be seen in Fig. 20, each brick, starting from the corners of the opening, projects over the opening slightly and tends to carry the upper wall. This means that each brick or other masonry unit will act as a cantilever, supporting the brickwork above it with its projection portion. The overlapping bricks on the two sides of the opening gradually approach each other from course to course until they meet in a point

over the center of the opening. Consequently, only the brick inside the triangle *ABC* needs to be supported by a lintel.

When more than one window or door opening occurs in a masonry wall, the lintels over such openings are required to support more of the masonry work. Again using a brick wall as an example, note that window opening *2* is directly over door opening *1* in Fig. 21. In a situation like this, the lintel over the door opening must support all of the
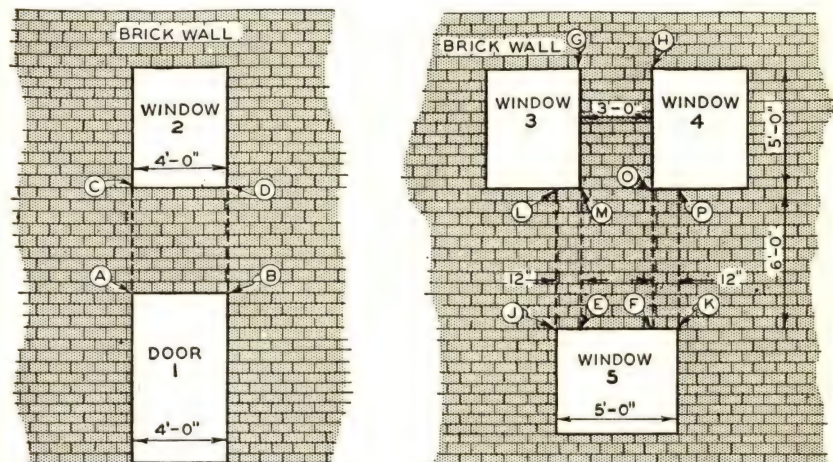
Fig. 21. Various Combinations of Window and Door Openings in a Brick Wall

brickwork in the area *CDAB*. This is because the corbeling effect just described does not exist where masonry walls are broken by two or more large openings. In other words, the lintel over the door opening must support not only the triangular area discussed in Fig. 20 but the balance of the area as well. This area is known technically as a *spandrel*.

Windows *3*, *4*, and *5* present another common condition. In this example, the lintel over window opening *5* must support the column of brickwork *GHEF* plus the areas of brickwork marked *LMJE* and *OPFK*. Regarding column *GHEF*, it is safe to assume that above line *GH* the corbeling effect of the brickwork will support the wall without any help from the lintel over window *5*.

There is still another common condition concerning lintels over window and door openings which must be considered. Fig. 22 shows a

section and elevation plan of a brick wall between its footing and a point just above the second floor window. The door opening is below the place in the wall where the second floor joists are supported. This

ELEVATION VIEW   SECTION VIEW
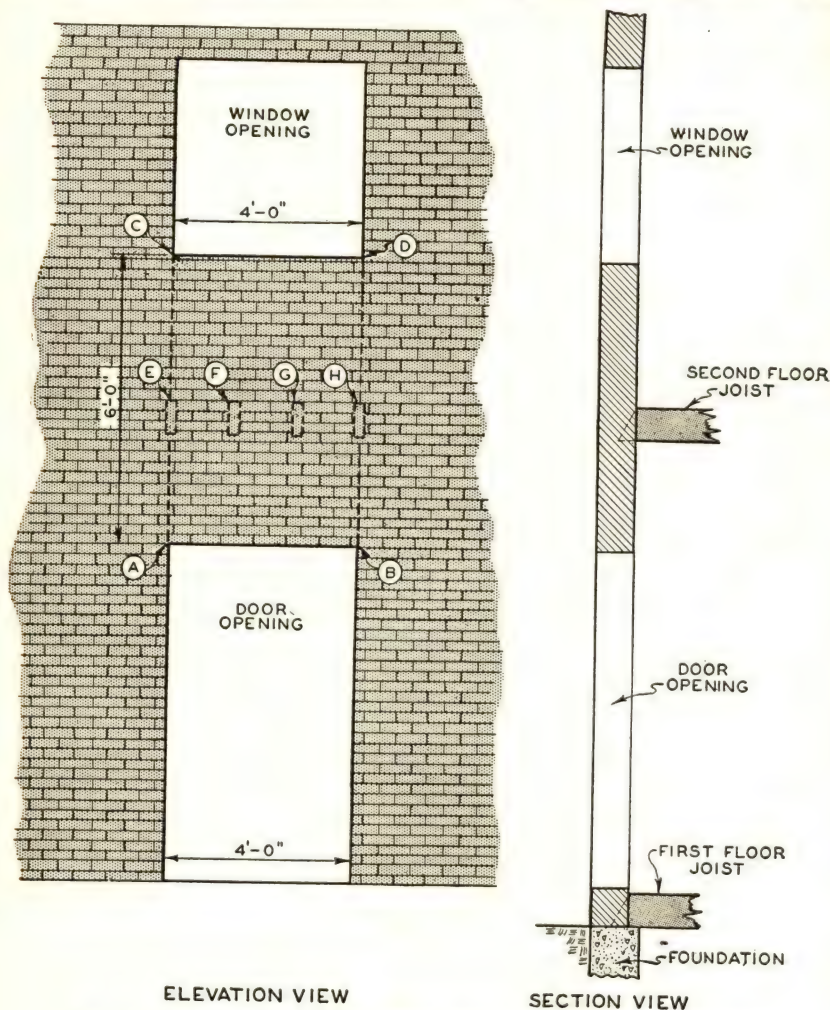
Fig. 22. Example of Brick Wall Where Door Opening Lintel Must Support Second Floor Load in Addition to Spandrel

means that the lintel over the door opening must support not only the area marked $CDAB$ but the loads from the joists E, F, G, and H as well. This condition pertaining to joist loads occurs in only two

sides of a building where wood or steel joists are employed because the joists run parallel to the other two sides of the building. If concrete floors are used, floor loads must be included in the calculations for openings on all sides of the building because such a floor is supported by all four walls.

When lintels are being selected for top story window openings, it must be remembered that attic floor joists and roof loads must be considered as was just explained for second floor joists. The same conditions apply because where wood or steel joists are used, they are supported by only two walls of the house. The same situation exists for flat roofs where rafters are used.
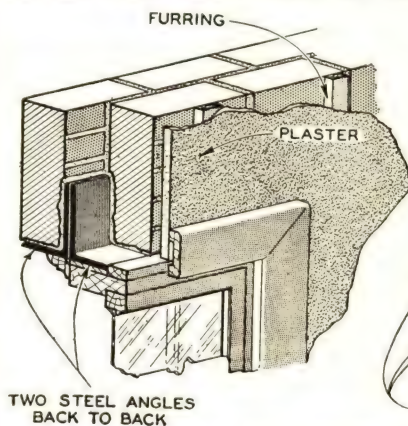
Fig. 23. Steel Angles Forming Lintel in Eight-Inch Brick Wall
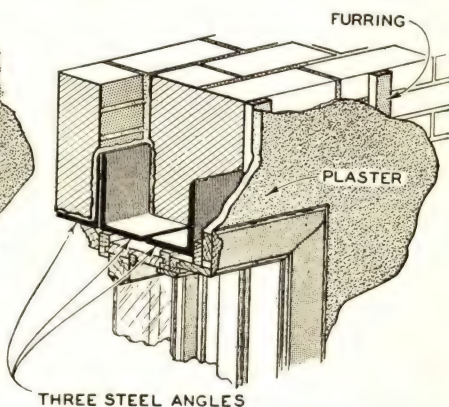
Fig. 24. Steel Angles Forming Lintel in Twelve-Inch Brick Wall

Every window, door, or any other kind of opening in a wall built of individual masonry units must have a lintel over it. The support and load conditions for these lintels can be determined if the foregoing explanations are kept in mind.

KINDS OF LINTELS

In the early days before the use of steel and reinforced concrete, masons used heavy oak timbers as lintels. Such lintels were never fully satisfactory because they were subject to shrinkage which caused the masonry they supported to crack. In modern construction, steel and reinforced concrete are used for lintels and only occasionally is wood used.

Steel Angles.   Steel angles of various sizes are used for lintels more than any other materials. They are easy to handle, easy to lay, and allow the surrounding masonry to be laid with less trouble than lintels of other kinds.

In 8″ brick walls it is common practice to use two angles placed back to back over a window or door opening. Fig. 23 shows how the angles are placed relative to the wall and the other units of the opening. If angles which have legs of unequal length are used, the
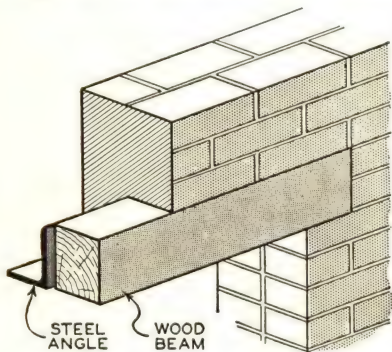
Fig. 25. Steel Angle and Wood Beam Forming Lintel for Window in Eight-Inch Brick Wall
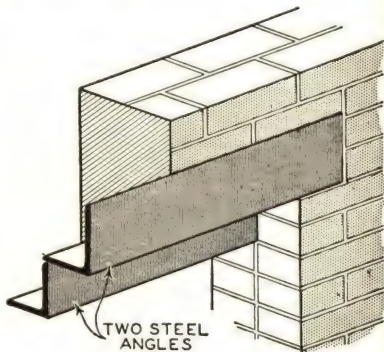
Fig. 26. Steel Angles Forming Lintel for Casement Window in Eight-Inch Brick Wall

longest leg is generally placed in the vertical position because the angle is stronger when set in that manner.

In walls greater than 8″ in thickness, more than two angles can be used. Fig. 24 illustrates a typical arrangement of the use of three angles.

For apartment buildings, some farm structures, and other small buildings having 8″ brick walls, some builders prefer to make up lintels using one steel angle along with a 4 x 6 wooden beam such as shown in Fig. 25. This scheme has some advantages so far as carpentry work is concerned. Such a combination generally forms a satisfactory lintel where the amount of masonry to be supported is not great and where no joist loads must be considered. Sometimes three 2 x 4's are nailed together to form a 4 x 6 beam. However, the solid 4 x 6 wood beam is best.

Fig. 26 shows the details of another way in which two steel angles can be used as a lintel over a casement window in an 8″ brick wall.

In a brick veneer wall such as shown in Fig. 27, the wood frame section of the wall over the opening is amply supported by the header which in this case is composed of two 2 x 4's nailed together. For this reason, only the 4" masonry section requires a lintel. This type of lintel serves equally well for stone or any other type of masonry veneer.

Steel Channels. Where openings occur in walls having thicknesses of 8" or more and where the openings are very wide, channels can be used to advantage to support large volumes of masonry and joist
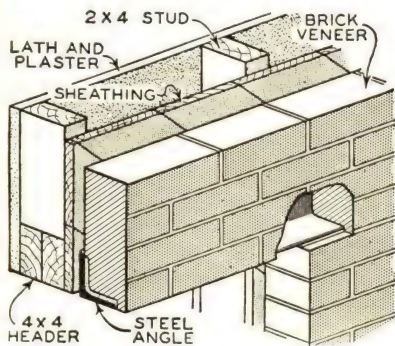
Fig. 27. Steel Angle Used as Lintel in Brick Veneer Wall Eight Inches in Thickness
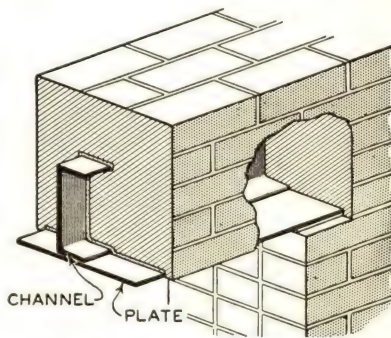
Fig. 28. Channel Used as Lintel in Walls Eight Inches or More in Thickness

loads. In Fig. 28 the channel is shown standing vertically. In such cases a plate (as indicated) is necessary to support the brickwork between the top of the channel and the plate. Above the channel the brickwork is bonded so that its weight is supported by the channel.

Steel I Beams. For wall of 8" or more in thickness and where the openings are wide or where large amounts of masonry or heavy joist loads must be supported, an **I** beam can be used as a lintel in much the same manner as was explained for the channel in Fig. 28. Or, as shown in Fig. 29, an **I** beam can be used to help support a stone lintel which is used for ornamentation. In like manner, a channel could be used in place of an **I** beam in Fig. 29. The shape of the steel selected for cases such as shown in Figs. 28 and 29 depends upon the shapes of the steel available and the amount of room in the wall. Sometimes a channel would fit into spaces such as in Fig. 29 better than an **I** beam. However, either makes a satisfactory lintel.

Steel Angles and Stone. For many buildings where considerable stonework is used for ornamentation on front elevations, stone blocks are required over the heads of window and door openings. In such cases, steel angles or channels in a horizontal position must carry the bulk of the load. Fig. 30 shows a 12″ brick wall where two angles are used in back of the stone. A channel, as shown by dash lines, could be used equally well or a **T** beam in an inverted position would serve the purpose. For very heavy loads, the channel or **T** beam would probably be used because of its stiffness and strength.
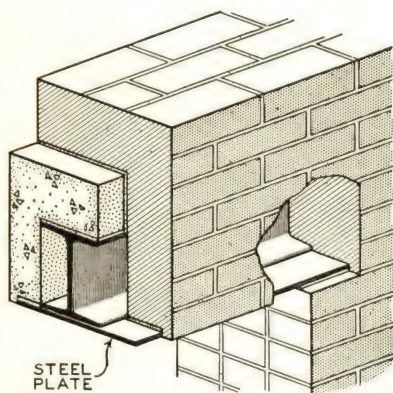
Fig. 29. An **I** Beam Used as Lintel in Walls Eight Inches or More in Thickness
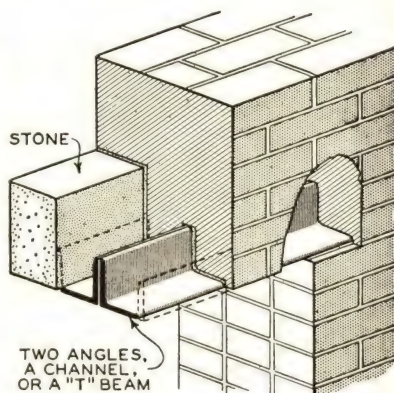
Fig. 30. Illustrating Use of Stone Lintel Backed Up by Two Angles, Channel, or **T** Beam

Reinforced Concrete Lintels. Reinforced concrete lintels can be used for openings in brick walls, concrete block walls, tile walls, and in other walls built of individual masonry units. For the sake of appearance, reinforced concrete lintels are used mostly with concrete block walls. This type of lintel is especially adapted to masonry farm buildings. The chief advantages of such lintels are that they can be made on the job if necessary and they are easy to lay. Where a stucco outside finish is planned, reinforced concrete lintels can be used to advantage in any type of masonry wall.

Fig. 31 illustrates the use of reinforced concrete lintels in a wall built of concrete blocks to which will be added an outside stucco finish. The lintel is the same thickness and height as the wall blocks and therefore becomes an integral part of the wall.
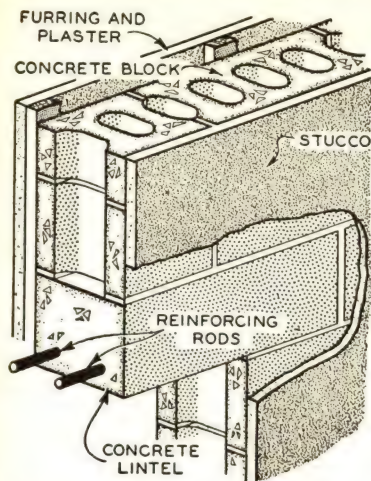
Fig. 31. Use of Precast Reinforced Concrete Lintel in Concrete Block Wall
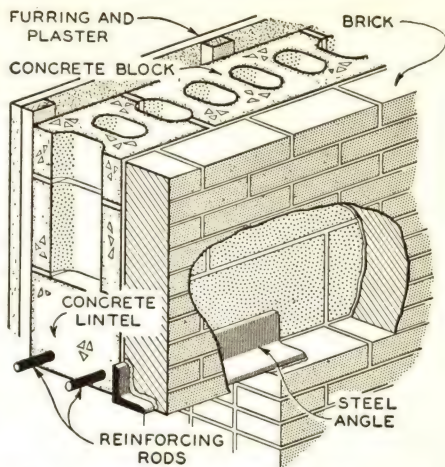
Fig. 32. Reinforced Concrete Lintel and Steel Angle in a Concrete Block Wall with Brick Veneer

Fig. 32 illustrates the use of a reinforced concrete lintel in a concrete block wall faced with a brick veneer. It should be noted that the concrete lintel supports the concrete block portion of the wall while a steel angle supports the brick facing.

Reinforced Concrete Split Lintels. Reinforced concrete split lintels are used in much the same manner as the one-piece concrete lintels. Typical use for this type of lintel is shown in Figs. 33 and 34 where it is illustrated in conjunction with wood and metal sash windows.

Hollow Tile Lintels. When walls are built using hollow clay tile units, the
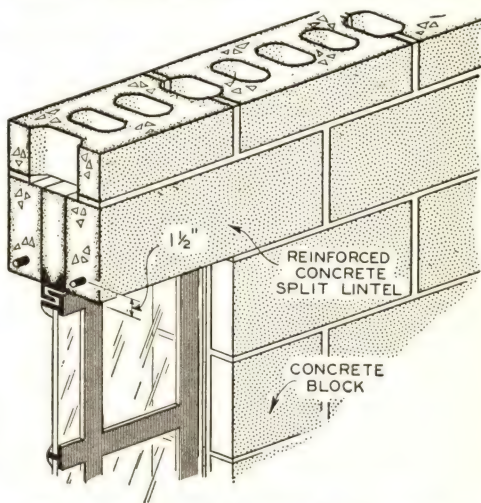
Fig. 33. Reinforced Concrete Split Lintel in Concrete Block Wall

lintels over window and door openings are sometimes made of a combination of hollow tile and reinforced concrete. This type of lintel is

illustrated in Fig. 35. Note that this lintel is strong enough to support joist loads as well as the weight of the wall above the opening. When lintels of any kind are used in tile walls, the hollow sections of the tile on either side of the opening must be strengthened in order to properly support the ends of the lintel. Fig. 36 shows how the cells in the tile are

WOOD SASH   **METAL SASH**
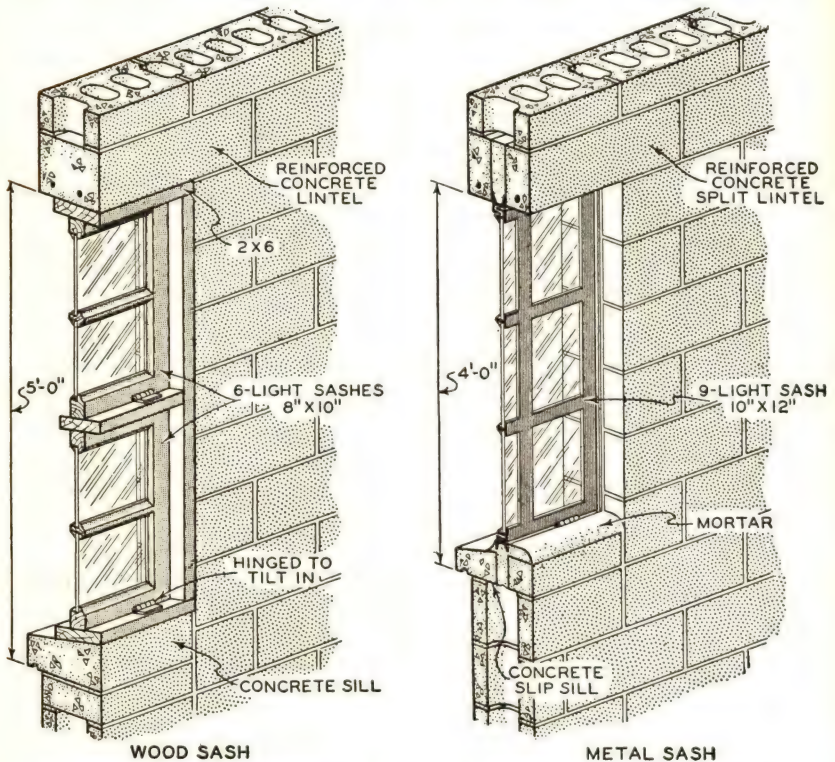
Fig. 34. Use of Reinforced Concrete Lintels in Concrete Block Walls for Wood and Metal Sash Windows

filled with concrete to give that portion of the wall the lintel bears on the strength of a column. In addition, it should be noted that the concrete and tile lintel is different from that shown in Fig. 35.

There are many kinds of lintels and just as many combinations of steel and concrete used in making them. However, the foregoing descriptions and explanations should be sufficient to give the reader a fairly comprehensive knowledge of the most common types in use.

SELECTION OF LINTELS

The selection of steel or reinforced concrete lintels must be done with the greatest care in order to avoid unsightly cracks in walls and to make them safe against failure. This is especially important in selecting lintels which will be called on to support heavy joist loads or roof loads in addition to the weight of the masonry above them.
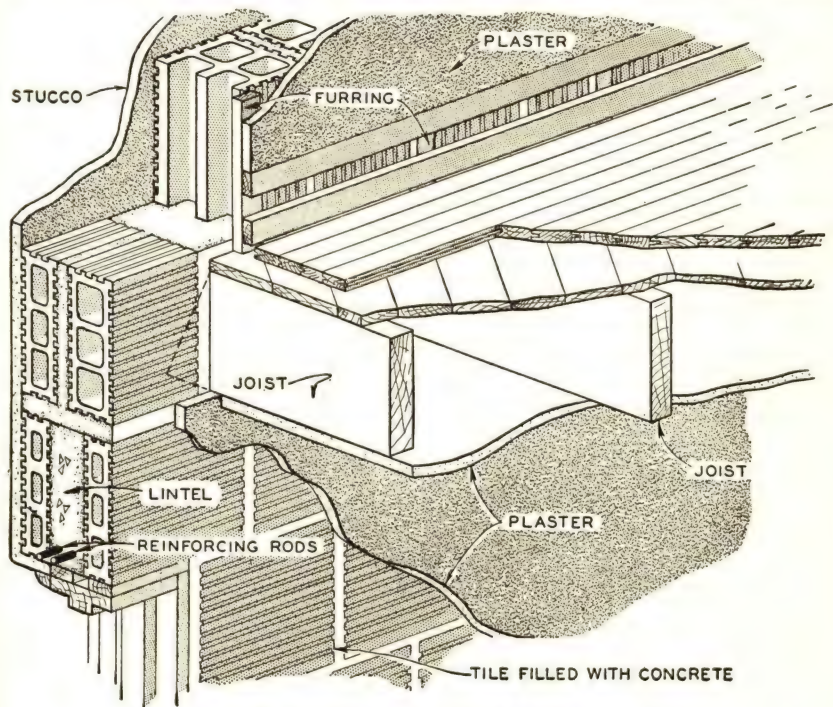
Fig. 35. Reinforced Tile Lintel for Tile Walls

If the exact size for various openings has not been specified by the architect or engineer, the mason should make his own selection of lintels on the basis of the following explanations and suggestions. Under no circumstances should the size and strength of a lintel be guessed at. Even in small buildings and over small openings, each and every lintel should be carefully considered and the correct one for the job selected.

Selection of Steel-Angle Lintels. In the construction of residences, apartment buildings, and medium-sized stores or industrial buildings,

brick walls of from 8″ to 12″ are generally specified. In the case of a brick or stone veneer wall, there will usually be just one steel angle or other steel shape in each lintel. Where a wall is of solid masonry, there will be two and sometimes three steel shapes incorporated in each lintel. Examples of these methods of building lintels will be found in Figs. 23, 24, 25, 26, 27, 28, 29, 30, and 32.
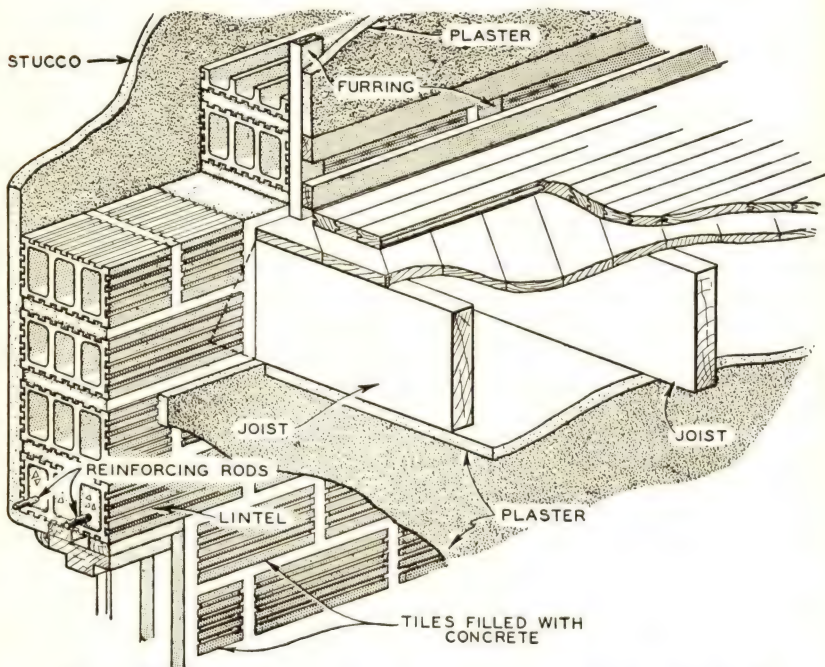
Fig. 36. Method of Reinforcing Jamb Sections around Opening in Tile Wall

In order to understand the selection of lintels, suppose the window in Fig. 20 is in a brick veneer wall, that there are no joists above it, and that the required lintel has to support only the 4″ brick masonry within the triangle *ABC* above it. The problem is to select a lintel with one steel angle which is strong enough to take care of the job.

The first step in determining what size steel angle to use in the lintel is to find the area of triangle *ABC*. Since the sides and two bottom angles are equal, it is an isosceles triangle. The area of a triangle is equal to one-half of the base multiplied by the altitude or the base multiplied by the altitude and divided by two. In a 45° isosceles

triangle, the altitude is equal to one-half of the base. Following these rules, the area of triangle *ABC* is four square feet.

The next step is to find the volume of brickwork in triangle *ABC*. The bricks are 4″ or ⅓′ thick. Therefore, multiplying the area (4 square feet) by ⅓ gives 1⅓ cubic feet. If the weight of brickwork is assumed to be 120 pounds per cubic foot, the weight of the brickwork in triangle *ABC* will be 120 × 1⅓, or 160 pounds.

The final step is the selection of a steel angle which will safely carry the total load of 160 pounds over the 4′0″ of the opening. If Tables I and II are examined, it will be seen that any number of angles of different sizes will be ample. Note the 3″ x 2″ x ¼″ angle in Table II. This angle can safely carry 4,270 pounds over a span of one foot. Over a 4′0″ span it could carry 4,270÷4, or 1,067.5 pounds. This angle is much stronger than is actually necessary but is selected because with the 3″ leg in a horizontal position, there is good footing for the brickwork. A much smaller angle such as a 2½″ x 2″ x ⅛″ could be used otherwise.

A slightly different problem is found in making the steel angle selection for the lintel of the door in Fig. 21. It can be assumed that the wall is one of brick and is 8″ in thickness, that there are no joist loads, and that the lintel required has only the spandrel section *CDAB* to support.

The first step is to find the area of the spandrel section *CDAB*. For the purpose of this problem it can be assumed that the distance from line *CD* to line *AB* is an even six feet. The area therefore is 4′0″ x 6′0″, or 24 square feet. The volume of this area is ⅔′ (8″ = ⅔′) × 24 or 16 cubic feet. This number multiplied by the weight of brickwork per cubic foot gives an answer of 1,920 pounds as the weight of area *CDAB*. Again, because of so little weight to be supported, any one of many angles can be selected. Since two angles will be needed because of the 8″ thickness of the wall, it is permissible to assume that half of the load or approximately 1,000 pounds will be carried by each of the two angles. Therefore, the 3″ x 2″ x ¼″ angle selected for the lintel of the window in Fig. 20 will be of sufficient size. The use of two angles, as shown in Fig. 26, gives adequate support and provides a 6″ surface for the brickwork.

The calculations involved in selecting a steel angle for a lintel are

further complicated when joists have their bearing in that section of wall supported by the lintel. The lintel then carries the weight of the brickwork as well as the load from the joists.

As an example, assume that in addition to the weight of the masonry work as illustrated in the last problem (Fig. 21), the lintel must support joist loads from the second floor. This situation is illustrated in Figs. 22 and 37. Four joists spaced on 16″ centers have
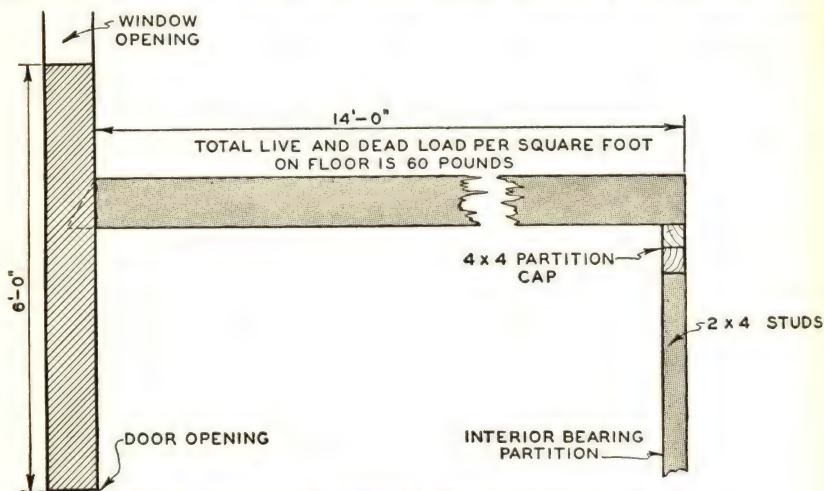
Fig. 37. Illustration of Method Used in Calculating Joist Loads

their bearing in the wall directly over the door. Since these joists are 14′ 0″ in length, the floor area involved is 56 square feet. If the total live and dead floor load is assumed to be 60 pounds per square foot, the total floor load supported by the four joists is 56 × 60, or 3,360 pounds. Half of this load will be supported by interior bearing partitions and the balance by the lintel over the door. The total load which the lintel must support is one-half of 3,360, or 1,680 pounds plus 1,920 pounds (the weight of the brickwork, same as for the last problem), or 3,600 pounds. By referring to Table I, it can be seen that a 3½″ x 3½″ x ¼″ angle will safely carry approximately 2,100 pounds across a 4′ 0″ span. Two such angles should be adequate to carry the 3,600-pound load required of the lintel in this example.

Two or more windows over a window or door opening in a wall also increase the complexities involved in selecting the proper steel

angle or angles to be used in the lintel. In order to illustrate the methods used, it must be assumed that windows *3, 4,* and *5* are in a 12″ brick wall, the second floor joists spaced on 12″ centers, and that the total floor load is 150 pounds per square foot.

The first step in the solution is to find the total weight of the brickwork. Column *GHEF* is 3′0″ wide and 11′0″ high and has an area of 33 square feet. The two small columns, *LMJE* and *OPFK*, are each 1′0″ wide and 6′0″ long, making an area of 12 square feet. The total area of the brickwork is 45 square feet. Since the wall is 12″ thick, the volume of the wall will be 45 cubic feet. The total weight of the brickwork is 120 × 45, or 5,400 pounds. The floor supported by the joists over window *5* is 5′0″ wide and 12′0″ long. Its area, therefore, will be 60 square feet. The total floor load will be 150 × 60, or 9,000 pounds. Since only half of this load will be carried by the lintel, the total weight on the lintel will be 4,500 plus 5,400, or 9,900 pounds.

Since the wall is 12″ thick, three angles will be required as shown in Fig. 24. Each angle will be required to support one-third of the total load, or 3,300 pounds. Table I shows that a 5″ x 3″ x 5⁄16″ angle will support 20,160 pounds over a 1′0″ span and 4,032 pounds over a 5′0″ span. Three of these angles will be satisfactory for use in the lintel.

A load of the size just calculated in the above example could be carried economically by a steel **I** beam. Table III shows that a 5″ **I** beam weighing 10 pounds per foot would carry the 9,900-pound load safely over the 5′0″ span. If the **I** beam were used, a 12″ x ½″ steel plate would be necessary to support the brickwork below the top of the beam. This is illustrated in Figs. 28 and 29.

When a lintel similar to the one shown in Fig. 25 is used, the selection procedure is the same as was described for steel angles except that the total weights and loads are divided between the wood beam and the steel angle. If the 4 x 6 wood beam is expected to handle half the load, then it and the steel angle must be selected on that basis.

When extremely heavy loads occur over wide openings and where heavy floor loads are expected, the use of **I** beams, channels, and combinations of them are sometimes necessary. Large lintels such as these are selected as was described for the procedures involved in selecting

beams. If complicated loadings are encountered, it is recommended that a structural engineer be consulted. Quite frequently, the suppliers of steel are able to be of help in the proper selection of beams and lintels and they can be consulted.

The deflection of steel lintels should be carefully considered when making selections for specific job purposes, just as it was an important factor in selecting steel beams. The tendency for steel angles and beams to bend under stress can be offset by using an angle or beam which is slightly heavier than is absolutely necessary. Their stiffness will generally be sufficient to prevent any appreciable deflection.

Selection of Reinforced Concrete Lintels.[3] Reinforced concrete lintels must be carefully selected and special distinction made between
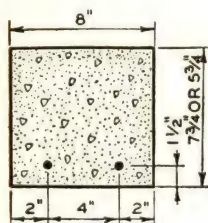
TABLE VIII. REINFORCED CONCRETE LINTELS
FOR SUPPORTING WEIGHT OF MASONRY
ABOVE OPENINGS ONLY

Size of Lintel		Clear Span of Lintel Ft.	Bottom Reinforcement	
Height In.	Width In.		No. Bars	Size of Bars
5¾	8	Up to 7	2	⅜″ round deformed
5¾	8	7 to 8	2	½″ round deformed
7¾	8	Up to 8	2	⅜″ round deformed
7¾	8	8 to 10	2	½″ round deformed

those supporting only the weight of the masonry wall and those supporting joist loads as well. Since such lintels are used principally in concrete block walls, this information applies only to concrete block masonry.

Concrete lintels over door and window openings are usually 8″ wide and either 5¾″ or 7¾″ high in order to fit into walls built of 8″ x 8″ x 16″ units. If blocks of a different size are used, the dimensions of the lintel must vary accordingly.

Lintels which are not over 3′ 0″ in length and which do not carry joist loads need not be reinforced. For longer lintels, both for use in supporting wall loads and wall loads plus joist loads, two to four reinforcing bars ½″ to 1″ in diameter are required.

The accompanying design tables should be carefully studied with these points kept in mind.

Tables VIII and IX are for lintels supporting the weight of the wall only as was explained using Fig. 20 as an example. Table X is for

[3]Data by permission of the Portland Cement Association, Chicago, Illinois.

lintels which support joist loads in addition to the weight of the wall. (It should be noted that the data in Table X also applies where concrete floors are used.) To simplify Table X, the floor load is assumed to be not more than 85 pounds per square foot, including both live and dead loads. The span of the joists for concrete floors is assumed to be 20 feet. This is equivalent to a total joist load of 850 pounds per lineal foot of lintel which should not be excessive.

Note that stirrups are not required for the lintels described in Tables VIII and XI but are necessary for the lintels in Table X with the exception of the 3′ 0″ lintel span. All stirrups are designed for No. 6 gauge wire and may be formed as shown in Table X.
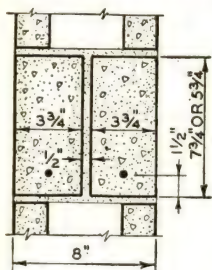
TABLE IX. REINFORCED CONCRETE SPLIT LINTELS
FOR SUPPORTING WEIGHT OF MASONRY
ABOVE OPENINGS ONLY

Size of Lintel		Clear Span of Lintel Ft.	Bottom Reinforcement—Each Section	
Height In.	Width In.		No. Bars	Size of Bars
5¾	3¾	Up to 7	1	⅜″ round deformed
5¾	3¾	7 to 8	1	½″ round deformed
7¾	3¾	Up to 8	1	⅜″ round deformed
7¾	3¾	8 to 10	1	½″ round deformed

From this information it can be seen that reinforced concrete lintels for all ordinary buildings, and farm buildings especially, can be selected without the calculations required in selecting steel lintels.

If reinforced concrete lintels are to be used over larger openings or where floor or joist loadings are greater than was assumed in Tables VIII, XI, and X, a structural engineer should be consulted regarding the necessary lintel dimensions and the required reinforcement.

Many lumber retailers and building material dealers carry concrete lintels in stock. In cases where these lintels can not be purchased, they can be made on the job using simple forms.

Selection of Reinforced Tile Lintels. The design of this type of lintel is intricate and a structural engineer should be consulted if reinforced tile lintels are to be used.

HOW TO MAKE REINFORCED CONCRETE LINTELS

Forms. Fig. 38 shows an easily made form which can be used for pouring individual lintels of one size and length. The legends explain its construction fully. Forms for other lengths and widths can

TABLE X. REINFORCED CONCRETE LINTELS FOR SUPPORTING WEIGHT OF MASONRY AND JOIST LOADS AS WELL

| Size of Lintel | | Clear Span of Lintel Ft. | Reinforcement | | Web Reinforcement No. 6 Gauge Wire Stirrups. Spacings in Inches from End of Lintel—Both Ends the Same |
Height In.	Width In.		Top	Bottom	
7¾	8	3	None	2—⅜" round	No stirrups required
7¾	8	4	2—⅜" round	2—½" round	3 stirrups, Sp.: 2, 3, 3
7¾	8	5	2—⅜" round	2—⅝" round	5 stirrups, Sp.: 2, 3, 3, 3, 3
7¾	8	6	2—¾" round	2—¾" round	7 stirrups, Sp.: 2, 3, 3, 3, 3, 3, 3
7¾	8	7	2—1" round	2—1" round	9 stirrups, Sp.: 2, 3, 3, 3, 3, 3, 3, 3, 3

ONE-PIECE LINTEL
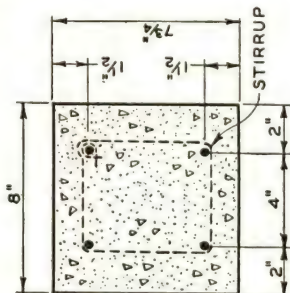
ADDITIONAL TYPES OF STIRRUPS ONE-PIECE LINTEL

TIE WITH WIRE
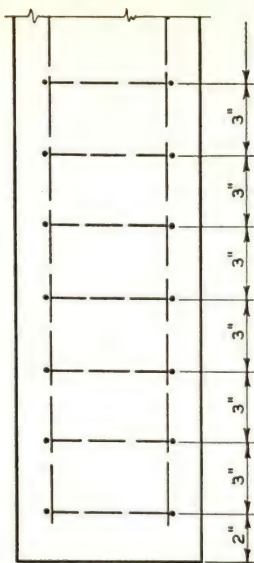
LONGITUDINAL SECTION TYPICAL ONE-PIECE LINTEL

be made just as easily. By using a large platform and 2 x 8's as partition pieces for the lintel sides, a gang form can be made. Or, a long form can be made and a plug used so as to allow the pouring of lintels of varying lengths. The forms for split lintels are made in a similar manner except that they should stand on edge.

How to Mix Concrete. Concrete for reinforced lintels can be made with a $1:2\frac{1}{2}:3$ mix and five gallons of water for average sand per sack of cement. This should produce a mixture plastic enough to be placed and tamped handily in the forms. If a trial mix proves to be too wet, add more sand or aggregate until the mix will stand in mounds without running.
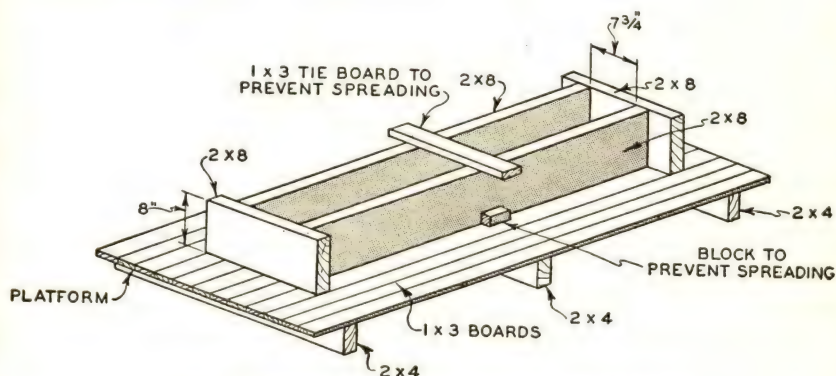
Fig. 38. Form for Pouring Reinforced Concrete Lintel

How to Prepare the Reinforcing Bars. Where no stirrups are necessary in a lintel, the required kind and size of rod (a little shorter than the length of the lintel) is purchased according to the data furnished in Tables VIII and IX. If the rods cannot be purchased in the exact length desired, the supplier probably will have shears for cutting them.

Where stirrups are required, the wire is first cut to length and then formed by machine in the supplier's warehouse. It is the supplier's job to form the wire if he cannot supply preformed wire. Occasionally, the complete assembly of rods and stirrups can be purchased. If this is not possible, it is a simple matter to space the stirrups correctly and tie the rods to them with lighter wire.

How to Place Concrete and Rods. For one-piece lintels without stirrups, first place 1½″ of concrete in the bottom of the form. The edges and corners should be spaded well. The rods are then placed on top of this concrete according to the dimensions given in Table VIII. Care should be taken to see that the reinforcing rods do not touch either end of the form. The remainder of the concrete is poured and spaded to insure smooth sides. Care should be taken when doing the spading to leave the reinforcing rods undisturbed. The top of the lintel is smoothed level with a trowel.

The concrete and single rods for split lintels are placed in a similar manner. The procedure for pouring one-piece lintels with stirrups is the same as for split lintels and one-piece lintels without stirrups except that greater care must be observed so as not to displace the reinforcement. Table X gives the correct stirrup spacing and position.

During warm weather, forms can be removed safely two days after pouring. However, the lintels should not be used for at least three weeks in order that they may first acquire nearly full strength. In cold weather, forms should not be removed for from five to seven days after pouring and the lintels should not be used for at least five weeks.

HOW TO SET LINTELS

Steel Lintels. When the brickwork has been laid up to the window height, care should be taken to smooth the joints so that no mortar extends up beyond the horizontal surface of the bricks where the lintel will be set. This will avoid the presence of uneven spots in the bearing area at a later time when the lintels are lifted into place.

In most cases, the steel angles selected for a lintel such as shown in Fig. 23, have horizontal legs of such a length that they do not quite reach the edge of the brick wall. This is illustrated more clearly in Fig. 39. Since the outside face of a brick wall would not look well if the edge of the angle extended to the edge of the bricks, the length of the legs is an important factor in selection.

The length of the angles should be sufficient to allow at least 4″ of bearing on both sides of the opening as shown in Fig. 39. For openings larger than 3′0″, and where loads are heavy, the bearing surface should be increased up to 12 inches. Bearing surfaces are important for two reasons. Ample bearing surface prevents any tendency for the ends

of the angles to rise upward and crack the brickwork over them. In addition, ample bearing surface provides large columns of brickwork (see Fig. 39) which support the angles and the loads on them.

Angles should be placed back to back as indicated in Figs. 23 and 39, and centered carefully over the walls. Before finally setting the angles, a mortar bed should be spread over the bearing areas. This provides a cushion for the angles and makes it possible to set them in the correct position horizontally and vertically. The angles should be pressed down until the mortar bed is the same thickness approximately as the brick joints.
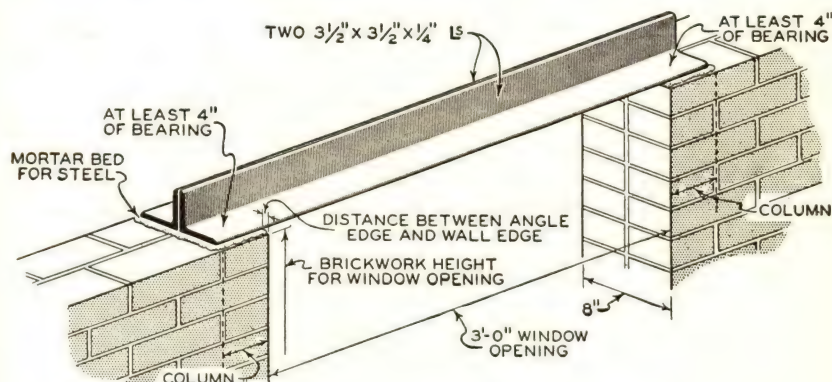
Fig. 39. Method of Placing Steel Angle Lintels

When setting lintels such as shown in Fig. 25, the same procedure as just explained is followed. The wood beam is set on a mortar bed along with the angle. Where two angles are used as illustrated in Fig. 26, the first or lower angle is set and the brickwork laid up to the point where the second angle is set.

For a part stone lintel such as shown in Fig. 30, the stone is placed first on a bed of mortar the same thickness as for the brick joints. The angles, **T** beam, or channel, is then placed as explained for any of the other typical examples.

Where an **I** beam or channel is used as a lintel, as in Fig. 28, the plate is set first following the procedures already described, making certain it is level at both bearing points. The channel or **I** beam is then placed on the plate and the brickwork laid on and around both

members. When the channels or **I** beams for this kind of lintel are longer than the plate and extend over the brickwork at either end, the ends of the member are set in mortar beds in the usual manner.

Reinforced Concrete Lintels. When the concrete blocks have been laid to the window opening height, care should be taken to smooth the joints so that no mortar extends up beyond the horizontal surface of the blocks near the bearing area.
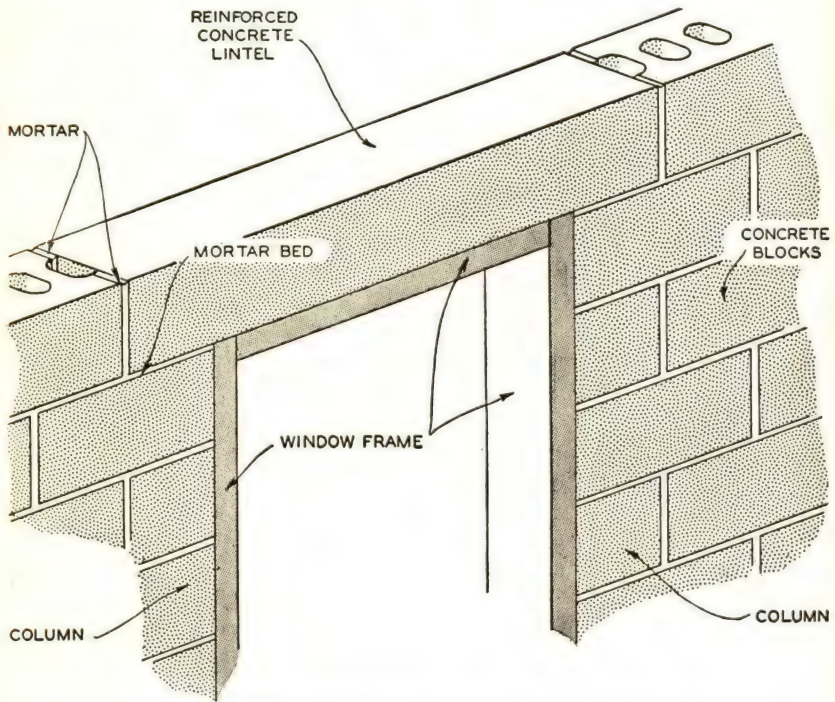
Fig. 40. Precast Concrete Lintel in Place over Window Frame

The length of reinforced concrete lintels should be ample to provide a bearing surface of at least 8″ for ordinary openings and up to 12″ or more for large openings and heavy loads. Bearing surface in the case of concrete blocks is important because of the column on either side of the opening, as explained in Fig. 39.

Figs. 34 and 40 show how reinforced concrete lintels are placed. Note that the lintels must be set on mortar beds and that they must line up exactly with adjoining concrete blocks. Note that split rein-

forced concrete lintels, as shown in Fig. 34, are set so that their outside faces are flush with the wall surface. This leaves an air space between the two halves of the lintel.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

BEAMS

DO YOU KNOW

1. Why the loads on beams are calculated beginning at the top of a structure?

Answer. Because the loads gradually increase from top to bottom.

2. Why plates or short lengths of I beams are sometimes put under the bearing ends of I beams, especially in brick walls?

Answer. To distribute the load over a greater portion of the wall and thus reduce the load on the wall at a point directly under the beam end.

3. Why spaces between precast concrete joists are filled when they are supported by an I beam?

Answer. They act as bridging and keep the precast joint erect.

4. Where reinforced concrete T beams are usually used?

Answer. They are always used as an integral part of reinforced concrete floors.

5. What the purpose is of 4″ brick pilasters under beam ends in connection with brick or concrete walls or foundations?

Answer. To help carry the load from the beam end in cases where the bearing in the wall or foundation is the minimum 4 inches.

6. If an angle is stronger or weaker when its longest leg is in a vertical position?

Answer. Much stronger.

7. If it would be wise to calculate the deflection of an I beam which is to be used for a ceiling structure?

Answer. If excessive deflection took place, the ceiling plaster would probably crack.

8. What the safe load is for a 5″ x 4″ x ⅞″ angle over a 4′ 0″ span?

Answer. Table II shows that such an angle can safely carry 35,310 pounds over a 1′ 0″ span. For a 4′ 0″ span, the angle can safely carry 35,310÷4, or 8,827.5 pounds.

9. What a good live and dead load per square foot is for an attic floor?

Answer. A live load of 40 pounds and a dead load of 16 pounds per square foot is considered average.

10. What size beam would be used if an I beam with a moment of inertia of 140.0 is employed in an erect position?

Answer. From Table V it can be seen that 140.0 is nearest to 145. 8. Therefore, a 10″ I beam weighing 35 pounds per foot would be used.

11. How Tables III and IV should be used if it is assumed that the steel in beams will withstand a bending stress of 20,000 pounds per square inch?

Answer. The safe loads in the tables should be increased by 25 per cent.

12. How the bearing ends of I beams are secured at the tops of Lally columns?

Answer. By four bolts from the top of the column and sometimes by a plate which is bolted to the ends of the I beam webs.

13. Upon what three things the amount of deflection of a steel beam depends?

Answer. Upon the load, the length of the span of the beam, and the moment of inertia of the beam.

14. Why steel beams are generally used in the first floor construction of a residence or apartment building?

Answer. To avoid the necessity of bearing partitions in the basement.

15. How the end of a joist may be supported and held in place by an I beam?

Answer. By the use of joist hangers.

REVIEW QUESTIONS

1. Explain what is meant by the term "load."
2. What is the span of a beam?
3. What is the bearing surface for a beam?
4. Explain how to calculate the moment of inertia for a beam.
5. Where are stirrups used?
6. How many reinforcing bars are in each precast joist?
7. Explain how wood beams are supported by wood columns.
8. Explain how to calculate the weight of a partition not directly over a beam.
9. Does the weight of an I beam have to be included in the load calculations?
10. What mix is recommended for reinforced concrete beams?
11. How is the brickwork of an 8″ wall carried above an I beam which has only a 5″ flange?
12. Explain the theory of wind pressure with relation to the calculation of outside wall loads.
13. Describe a flitch beam.
14. Describe the method of determining the floor area supported by a beam.
15. Explain how to calculate the deflection for a beam.

LINTELS

DO YOU KNOW

1. What two factors need to be considered when selecting steel lintels to carry masonry walls?

Answer. The strength and the stiffness of the lintel.

2. What the common cause of cracks over window and door openings in masonry walls is?

Answer. Too much deflection in the lintels.

3. How cracks can be avoided?

Answer. By selecting lintels stiff enough so that there will be no deflection under load.

4. Why it is necessary for a lintel to support all of the brickwork in a spandrel?

Answer. Because corbeling properties do not exist in such an area.

5. Under what conditions lintels must support part of floor loads?

Answer. When the brick wall directly over the opening supports joist ends.

6. What a reinforced concrete split lintel is?

Answer. It is composed of two pieces of concrete laid up so that there is an air space between them.

7. What type of lintel is best to use in concrete block walls and why?

Answer. A reinforced concrete lintel, because the lintel can be made to replace three or more of the blocks and thus becomes part of the wall.

8. What the necessary items are that must be considered in the selection of steel angle lintels for an opening in a brick wall?

Answer. Weight of the brickwork and all other loads directly above the opening, one or more angles which will support the load without too much deflection, and an angle whose horizontal leg is wide enough to support bricks nicely but not so wide as to show at the surface of the wall.

9. When stirrups are necessary in reinforced concrete lintels?

Answer. When the load carried by such a lintel includes floor loads.

10. What type of reinforced concrete lintel should be used over an opening where a metal sash window is to be used?

Answer. The split type.

11. How many bars, and what size, should be used in a solid reinforced concrete lintel over a window opening having a clear span of not over 8′ 0″ and where no floor loads need be considered?

Answer. Two bars, each ⅜″ diameter.

12. What should be done to the brick bearing surfaces of a wall before a steel lintel is laid?

Answer. They should be smoothed and a mortar bed put down.

REVIEW QUESTIONS

1. Explain the corbeling property theory relative to the brickwork over an opening in a brick wall.

2. What is a spandrel in connection with lintels?

3. What is the longest concrete lintel that can be used without steel reinforcing?

4. How many reinforcing bars are required in each side of a split lintel?

5. Explain how to make forms for pouring reinforced concrete lintels.

6. Explain how reinforcing rods are placed in concrete lintels.

7. Explain how to find the weight of one square foot of 8″ brick wall.

8. Explain how to use the load table for angles in the selection of angle lintels.

9. How much bearing is required for steel and reinforced concrete lintels?

10. Explain what type of lintel could be used to advantage in a concrete block wall having a brick veneer.

11. How far from the bottom of a solid reinforced concrete lintel should the reinforcing bars be?

Column Design and Construction

1. *What are some of the more popular types of columns and what conditions govern their use in a building?*
2. *What are some of the advantages gained through the use of columns?*
3. *What is meant by the term "safety factor" and how does it apply to the various types of columns?*
4. *How is the proper size for a column determined?*
5. *What is the correct procedure for installing the various types of columns?*

INTRODUCTION TO CHAPTER V

The column is defined architecturally as a vertical support which is round or polygonal in cross section. It is one of the most fascinating phases of architecture that it is possible to study. No matter from what point of view an approach to it is made—structural, architectural, cultural, historical—the column will always rank high in importance and interest. The chief reason for this is the extreme age of the column. The first use of this architectural device undoubtedly consisted in the erection of simple tree trunks followed at a later date by wooden columns which were tapered and placed on stone bases with the small end down. The use of these base stones was almost universal and many of them are still in existence.

The Egyptians were one of the first people to produce noteworthy examples of the column in stone. Their work in this respect was distinctive and remained relatively unchanged for 3,000 years. For the most part their columns resembled a natural growth suggesting a grouped collection of flowering or budding stalks bound together near the top and at the base, and decorated to heighten the effect.

The development of Greek architecture was similar to that of the Egyptians because of the same building material limitations. The wood, stone, and mud at their disposal compelled them to adopt the post-and-lintel system as had been done in Egypt. The Greek characteristics of patience and genius finally developed three distinct types of columns which were later classified by the Romans according to their "order." These orders, *Doric, Ionic,* and *Corinthian,* were established so that exact proportionate dimensions for every feature of the column could be furnished. Given the diameter of the column, the entire order could be constructed mechanically. The three orders were adopted by the Romans, with variations, by the middle of the first century B.C. To them the Romans added the *Tuscan* and *Composite* orders. With varying

degrees of modification, these five orders have formed the basis of classic architecture from the time of the Romans to the present day.

Another form of the column, sometimes called a pillar, is a square rather than a round support. It has always been considered less decorative than the round column and for that reason it has never been widely used. However, the Egyptians made extensive use of this form of column in building their obelisks. These structures were upright monuments about 100 feet in height, square in section, and had sides which sloped gradually and evenly, ending in a small pyramid, the faces of which inclined at 60°. They were quarried in one piece and usually had a maximum thickness of one-tenth their height. The Egyptian obelisk has been copied frequently. An excellent example is the Washington Monument, completed in 1884 in Washington, D.C.

Modern use of the column differs greatly from that of the Egyptian and Greek builders. Because of our use of steel, reinforced concrete, and other building materials not available to the Egyptians and Greeks, the need for columns in our architecture has been reduced to the simplest terms. Great progress has been made in architectural design but columns still serve a definite purpose, even in small structures such as homes and barns. The material in the following pages is devoted to the study of these columns, particularly with regard to their application to the *small* structure. The various types of columns are discussed and their methods of placement described. Other similar problems are introduced along with an analysis of the best methods for handling them. A careful study of this chapter on columns and their design and construction will leave little to be added to the fund of knowledge the mason should have concerning columns.

NECESSITY FOR COLUMNS

In practically all cases where beams are used in residences, farm buildings, and other small structures, there must be one or more supporting members for the beams. These supporting members are commonly called posts, pillars, or columns. The term column is technically correct and is used throughout this chapter. Architects and engineers generally design the columns in a given structure just as they do the beams. But there are times when a mason must design columns as well as set or build them. In this chapter you will learn the theory of columns, their kinds and design, as well as how to build and install them. Columns, like beams, are of great importance because the safety of an entire structure depends upon them. Keep this in mind as you carefully study this chapter.

THEORY OF COLUMNS

It has already been pointed out that columns are the means of supporting beams. An exception to this statement occurs when one end

of a beam is supported by a foundation or side wall or where beams are used to support sections of walls. In such cases the walls directly under the bearing surfaces of the beams act as columns and must be strong enough to carry the loads safely without failing in any way.
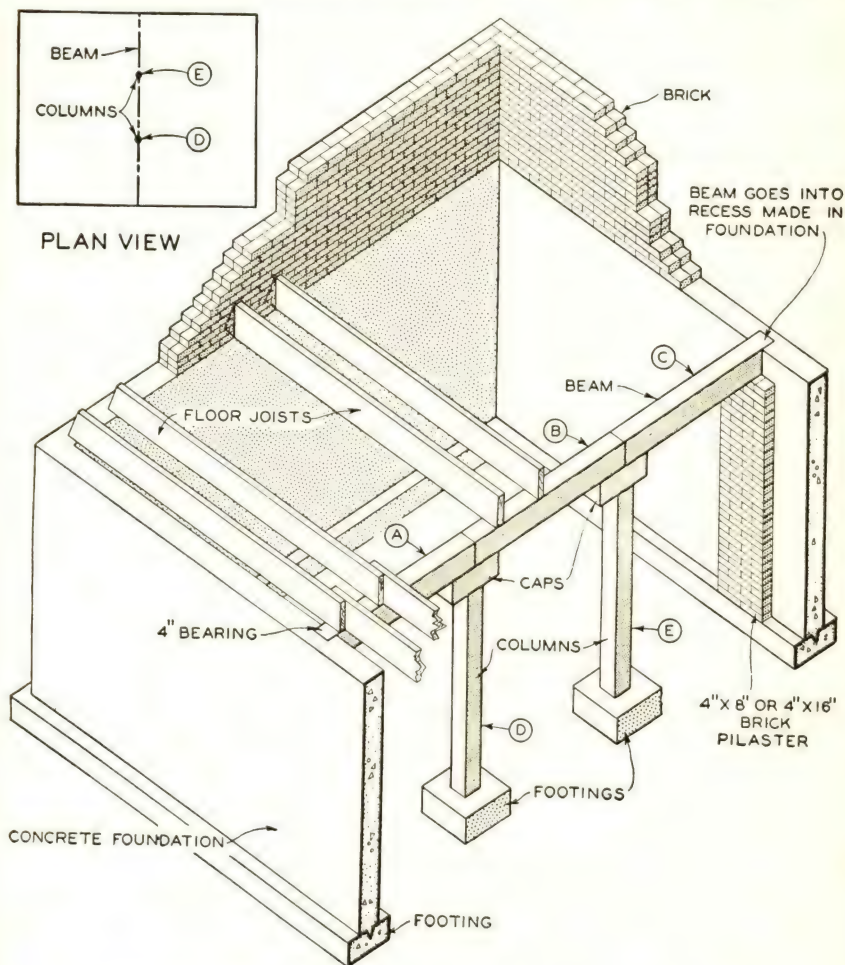
Fig. 1. Wood Columns for Use with Wood Beams in Small Residence

The plan and pictorial view of a basement for a small barn, residence, or other building showing the joists, beams, and columns, is shown in Fig. 1. Note that the beam is composed of three parts, *A*, *B*,

and C, and that it is supported by columns D and E as well as by the foundation. Part A of the beam is supported at one end by the foundation and at the other by column D. Part B of the beam is supported at its ends by columns D and E. Part C of the beam is supported at one end by column E and at the other end by the foundation.

One of the important points stressed in Chapter IV was the limit in length of any beam due to its strength. A wood beam, it was pointed out, must be rather short in length because it is not strong enough even in large sizes to support heavy loads over long spans. It should be emphasized that even if a large wood beam in one piece strong enough to support safely heavy loads over long spans could be obtained, its depth would be so great as to cut down seriously the headroom in the basement. In addition, the cost of such a large wood beam would be prohibitive. For these reasons, beams of shorter lengths are used with columns where necessary, as shown in Fig. 1.

In many cases, one-piece steel **I** beams could be used which would carry the load safely. Again, the depth of the beam as well as its cost would make its use impractical. The same conditions are true also of reinforced concrete or other types of masonry beams. In order to insure building a safe structure, avoid prohibitive construction costs, and conserve basement headroom, beams of short length must be used in conjunction with columns.

The same reasoning also applies where beams are used to support haymow floors in barns or other floors above the first floor level.

There are some exceptions to these statements concerning beam lengths and loads, especially where headroom is not a problem. For example, the store and bakery building shown in Fig. 7 of Chapter IV has long, one-piece beams which support the second floor over the store and the roof over the bakery and garage. In this particular case no columns were wanted in the store for reasons which are apparent. Columns in the garage and bakery also would have been in the way. Headroom was not a problem because it was possible to support the underside of the beams at a level high enough in the outside walls to provide the desired ceiling heights.

In some cases it is desirable to have partitions in a basement or on the first floor of a building, as, for example, a barn. Such partitions are usually constructed of bricks or concrete blocks and thus are able to

serve as supports for one or more beam ends. Fig. 2 shows a small residence basement which has partitions between G and F and a beam and column between E and G instead of beams and columns running between E and F. This is the same residence basement as was shown in Fig. 3 of Chapter IV with the exception that the dimensions are slightly different. These partitions provide enclosed space for coal bins, garages, and other small rooms and, if built of bricks or concrete blocks, take the place of columns and beams. A steel beam would be required be-
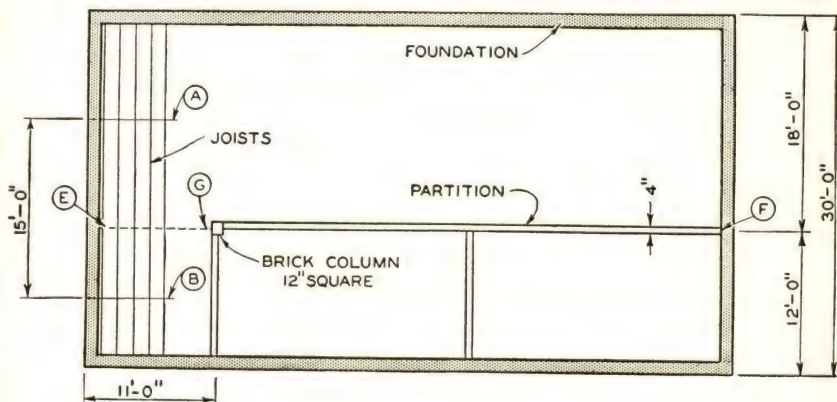
Fig. 2. Basement Partitions, When Required, Are Made of Masonry and Are Used to Support Floor Loads

tween E and G, however. At G the partition would have to be enlarged to form a column because one end of beam EG would have to be supported. The regular partition would not be strong enough to support it since it carries a *concentrated load*. This is explained as follows:

The side view of **I** beam EG is shown in Fig. 3. This beam spans a distance of 11′0 inches. The end at E is supported by the foundation wall while the other end at G is supported by the brick column which can be seen in Fig. 2. The arrows above the beam in Fig. 3 represent these joists. In order to make the problem easier to visualize, the first floor live and dead load[1] will be assumed as 60 pounds per square foot, the weight resulting from first floor partitions not being taken into consideration. The length of the floor area between lines A and B is 15′0″ while the width is 11′0 inches. If the combined live and dead load is 60 pounds per square foot and the area of the floor 165 square feet

[1]Load calculations are explained in detail in Chapter **IV**.

(15′ 0″ × 11′ 0″), the total floor load will be 165 × 60, or 9,900 pounds. Thus, the beam in Fig. 3 supports 9,900 of an *equally distributed load*. The load is said to be equally distributed because each joist along the beam has an equal load. For this reason, along every foot of the beam the load is equally distributed.

A beam with an equally distributed load and supported at its ends as shown in Fig. 3 in turn distributes half its load to each support. In other words, in Fig. 3, half of 9,900, or 4,950 pounds, is supported by the foundation and 4,950 pounds by the brick column. Each of these 4,950 pound loads is a concentrated load so far as the foundation and brick column are concerned because the beam causes the loads to fall at one spot on the brick column and at one spot on the foundation wall. If
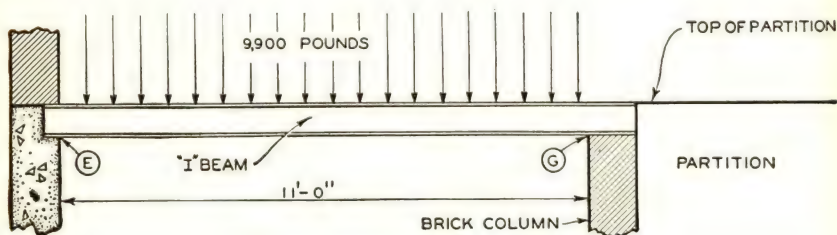
Fig. 3. Beam *EG* Shown in Fig. 2

the second floor and attic floor loads plus the loads resulting from the weight of partitions were added to the 9,900 pounds, the total weight beam *EG* would have to carry would probably be more than three times as great, or in the neighborhood of 32,000 pounds. In that event, each concentrated load would be about 16,000 pounds.

When uniformly distributed loads are carried, brick partitions such as those between *G* and *F* in Fig. 2 might possibly be as thin as four inches. Brick partitions are explained in greater detail in succeeding pages. However, a 4″ wall alone under the beam end at *G* would not be strong enough to support the concentrated load of 16,000 pounds. Therefore, the partition directly under the beam end bearing point is increased in size to the extent that the column thus formed is 12″ square.

In most cases the concrete foundation will be capable of safely supporting such a concentrated load. If the load is considered too great or if there is any doubt at all of the foundation's ability to support the load, a pilaster 4″ thick and 12″ wide is constructed.

KINDS OF COLUMNS

There are many kinds of columns. They differ according to the materials from which they are made and the various uses to which they are put. It will be found that very few exact recommendations are made as to the kinds of columns to use in specific places. This is due to the many varying factors relative to allowable costs, availability, and geographical locations. Generally speaking, the individual making the selection of columns chooses those types which he feels will serve
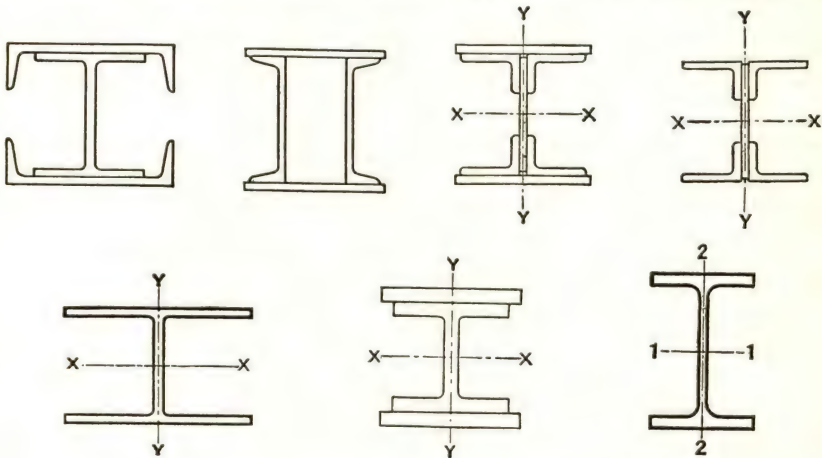
Fig. 4. Typical Steel Column Sections

the purpose to the best advantage. For example, an architect or mason may feel that steel columns should be used for a given structure. If steel columns are not easily obtained but concrete blocks are readily available, then it might be just as well to construct concrete block columns if their added size will not interfere with the planned use of the space they will occupy. Each situation where columns are required should be studied carefully and the type of column selected which best meets all of the conditions encountered.

Steel Columns. Practically all structural steel shapes such as angles, I beams, channels, and H beams are used as columns either individually or in combinations. Fig. 4 shows section views of several typical individual and built-up columns. Individual columns such as I's and H's are frequently used in small buildings. Those columns made of com-

binations of two or more shapes are used exclusively in the construction of large buildings, bridges, standpipes, grain elevators, warehouses, and similar structures. In this book only **I** and **H** beam columns are considered. Fig. 5 shows a typical **I** or **H** beam column along with a standard base. Note the method used in fastening the beams to the top of the column. If the beams in Fig. 1 had been steel **I**'s instead of wood, either **I** or **H** beam columns could have been used at *D* and *E*.
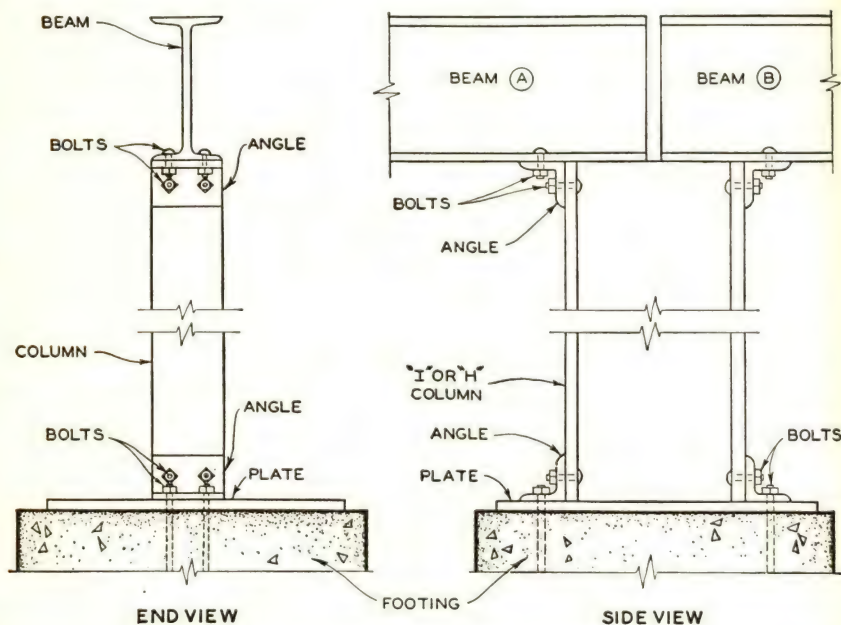
Fig. 5. Typical **I** or **H** Beam Column

Lally Columns. The column most widely used for residences, barns, apartments, and store buildings is known as the *Lally Column*. Such columns are made of cylindrical steel pipe which is filled with a 1:1½:3 mix of Portland cement concrete. Fig. 6 shows a Lally column, together with top plates and bases. The elevation view pictures a typical Lally column standing in its usual position. The section view shows the relationship between the steel pipe and the concrete filling. Two bases are shown, one with a cup and the other with a hole for a dowel. Also, two standard caps are pictured, one with brackets and the other without. The cap with the brackets is used where the beams being supported

are very heavy. Such beams require stronger bearings for their beam ends. Table I gives the dimensions for bolthole centers, g, for caps for columns of various sizes. These centers can be seen by referring to Fig. 5.
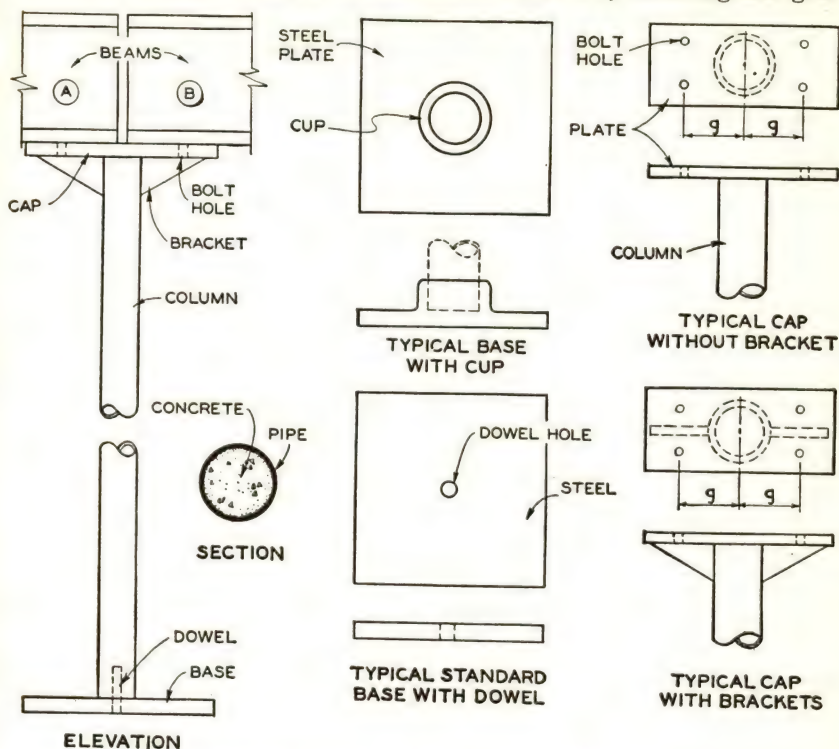
Fig. 6. Lally Column with Base and Cap Variations

If the beams in Fig. 1 had been steel **I** beams instead of the wood beams shown, Lally columns could have been used at D and E. The caps and bases would have been similar to those shown in Fig. 6. The steel beams shown with the barn roof and second floor framing in Fig. 4 of Chapter IV are supported by Lally columns. The **I** beams in the basements of residences, apartment buildings, and stores are usually supported by this type of column.

Table I gives the diameters of columns which may be purchased from the Lally Company of Chicago, Illinois. Upon receipt of an order, the Lally Company makes up these columns to the required lengths, fitting them with the type of cap required and with the proper bases.

Many building material dealers carry these columns in stock within the range of common diameters and lengths. Before planning the use of such columns, their availability, including the fittings, should be investigated at the local material sales yards. The dealers at such places should be able to give definite information regarding the sizes obtainable as well as the method of securing them if not carried in stock.

TABLE I. STANDARD STEEL BASES AND BOLTHOLE
DIMENSIONS FOR LALLY COLUMNS

DIAMETER OF COLUMN IN INCHES	g, FOR PLATE CAPS IN INCHES	g, FOR BRACKET CAPS IN INCHES	STANDARD STEEL BASE PLATES	
			Dimensions in Inches	Weight in Pounds
$3\frac{1}{2}$	3	$4\frac{1}{4}$	8 x 8 x $\frac{1}{2}$	9
4	3	$4\frac{1}{2}$	8 x 8 x $\frac{5}{8}$	12
$4\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{3}{4}$	10 x 10 x $\frac{5}{8}$	18
5	$3\frac{3}{4}$	5	10 x 10 x $\frac{3}{4}$	21
$5\frac{1}{2}$	4	$5\frac{1}{4}$	12 x 12 x $\frac{7}{8}$	36
$6\frac{5}{8}$	$4\frac{1}{2}$	$6\frac{1}{4}$	16 x 16 x 1	72
$7\frac{5}{8}$	5	$6\frac{3}{4}$	18 x 18 x 1	92
$8\frac{5}{8}$	$5\frac{1}{2}$	$7\frac{1}{4}$	18 x 18 x $1\frac{1}{8}$	104
$9\frac{5}{8}$	6	$7\frac{3}{4}$	20 x 20 x $1\frac{1}{4}$	142
$10\frac{3}{4}$	$6\frac{1}{2}$	$8\frac{1}{4}$	22 x 22 x $1\frac{1}{4}$	171
$12\frac{3}{4}$	7	9	24 x 24 x $1\frac{1}{2}$	245

Reinforced Concrete Columns. The use of this type of column is generally limited to buildings with reinforced concrete frame and floors. For example, if the building shown in Fig. 1 were to have a reinforced concrete floor, one or two reinforced concrete beams might be required along with two or more reinforced concrete columns to support the beams. However, this type of construction is rarely encountered or planned for in small buildings. Where floors and beams of this type are encountered, Lally columns would more than likely be used as shown in Fig. 7. The floor and beam detail at (A) could be used for a haymow floor or the roof of a small dairy barn.

Brick Columns. Brick columns are seldom used unless the basement partitions or foundations are constructed of bricks. One use for the brick column has already been explained in the description of the enlarged section of the brick partition at G in Fig. 2. This column supports one end of the beam which spans the distance between E and G.

In cases where brick foundations are made to serve as the bearing surface for heavily loaded beams, they are enlarged, forming pilasters, at the bearing points.

Where beam ends are supported by concrete foundations, brick pilasters are frequently built as shown in Fig. 1. The purpose of the pilas-

ter is, of course, to help support part of the load from the beam end, particularly if the foundation wall is only 8″ in thickness. An 8″ foundation will allow only 4″ of bearing surface for beam ends. The size of such pilasters depends on the load from the beam and on the amount of bearing surface available for the beam in the foundation.

If for any reason it is desired to use brick columns at such points as D and E in Fig. 1, they are easily constructed.
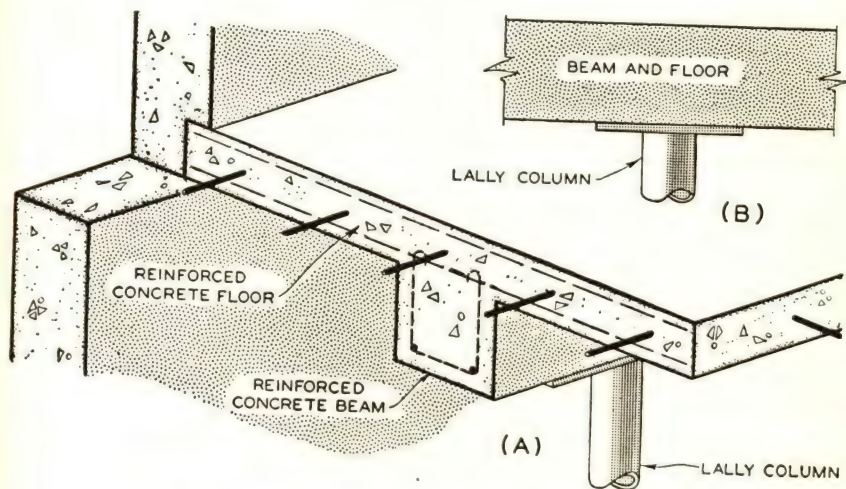
Fig. 7. Lally Columns Used to Support Concrete Beams

Concrete Block Columns. When basement partitions and foundations for residences, barns, and other small buildings are constructed of concrete blocks, it is sometimes necessary to build columns as a part of the partitions or foundations as a means of safely supporting the heavy loads from beams.

Suppose, for example, that the foundation and bearing partitions shown in Fig. 2 were made of concrete blocks. Beam EG, formerly discussed, imposes a large, concentrated load on the partition at point G. In order to make the corner of the partition strong enough, a column must be constructed as was previously described. If the holes in the blocks used to construct this column are filled with concrete, the column will have great strength and will be able to support the load from the beam safely.

Because of the excessive loads from some beams, it is occasionally desirable to strengthen concrete block foundations at the points where such beams have their bearing. For example, Beam *EG* is supported at one end by the foundation as shown in Fig. 2. Due to the heavy concentrated load from the beam and because concrete blocks are usually only 8″ in width, it would be wise to construct a "column" or pilaster against the foundation at *E*. If the load from the beam is not too great, the necessity for the pilaster ceases to exist. By filling the cores of the blocks with concrete for perhaps two blocks on either side of the beam bearing point, as well as directly under it, a column will be formed which will be strong enough to support the load safely.

Concrete block columns could be used in such places as columns *D* and *E* in Fig. 1. However, because of their size they are seldom selected as columns for such situations. As a general rule, Lally or wood columns are used because they occupy so little space. If the circumstances warrant the use of concrete block columns, they can be constructed readily enough.

Wood Columns. The pictorial view of the residence basement shown in Fig. 1 was drawn so as to illustrate the use of wood beams and columns. Wood columns, unlike built-up wood beams, must be made of a single piece of wood. They should never be constructed of two or more pieces of wood. Whenever wood columns are used, there should be a cap as shown in Fig. 1. The bottoms of wood columns can be placed directly on top of their footings without plates or any other anchoring device. The concrete floor, when it is poured, will be higher than the top of the footing and thus will prevent the column from moving in any direction.

Wood columns are made from any one of several kinds of wood. Their strength, therefore, will vary accordingly. This is one of the factors which should be taken into consideration when determining the size of the wood columns to be used on a job. Hard woods make stronger columns than do any of the soft woods.

SELECTION OF COLUMNS

In the selection of columns of all kinds, the consideration of their height (or length) in connection with the weight they will be expected to support is just as important as the selection of a beam for a specific

purpose. If too great a load is placed on a beam or if the beam is not large enough to handle the loads placed upon it, deflection or bending will occur followed possibly by complete failure of the member. If the load a column supports is too large, the column will tend to bow or bend at a point approximately halfway along its length. To overcome such tendencies, all columns are designed so as to have adequate relationship between their length and thickness. From the data supplied by the manufacturers of steel shapes, it is possible to select columns from tables which take these relationships into account. For other types of columns, this relationship must be calculated. A simple but acceptable method for making these calculations with the use of the table is explained in the following:

Steel Columns. When the end of a beam rests on a column, the load which the column must support is equal to the concentrated load at the end of the beam. Often a basement column or a first floor column will have to support the ends of two beams such as those indicated by the letters *A* and *B* in the side view of Fig. 5. In such a case, the load on the column is equal to the sum of the concentrated loads at the ends of both beams.

The size of the column should depend on the load it will be expected to carry as well as the length or height it must be. For example, the length of a column will be the distance from the basement floor up to the underside of the beams, or beam, which will rest on the top of the column. This is called the *effective length* or *unbraced length* of the column.

In the handbooks published by the various steel companies, and by the American Institute of Steel Construction, there are tables which give the safe loads in thousands of pounds which steel shapes, used as columns of various lengths, will support. One of these tables is reproduced here as Table II.

As the result of a great many years of study and experiment by scientists and engineers, certain rules have been developed for finding the loads which columns of different sizes, shapes, and lengths will safely support. Safe loads depend on the relation between the size and shape of the column and its length or height. The mathematics necessary for such exact calculations is an extremely complicated process. The data given in Table II was carefully prepared using just such exact

methods. Therefore, for all ordinary residences, barns, apartment buildings, and similar structures, it is safe to use the information contained in Table II.

As a means of understanding the function of this table, assume it is desired to select the correct **I** beam column for point *Y* in the plan and
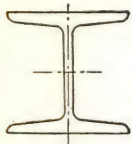
TABLE II. BEAM COLUMNS*—SAFE LOADS IN THOUSANDS OF POUNDS†

Effective Length in Feet	I Beams					H Beams							
Weight Lbs. per Ft.	8 In.	7 In.	6 In.	5 In.	4 In.	8 In.			6 In.			5 In.	4 In.
	18.4	15.3	12.5	10.0	7.7	37.7	34.3	32.6	26.7	24.1	22.8	18.9	13.8
3	69.3	57.5	46.9	37.3	28.5	143.0	130.0	123.6	100.9	91.1	86.2	71.1	51.9
4	69.3	56.7	44.4	33.5	24.0	143.0	130.0	123.6	100.9	91.1	86.2	71.1	51.9
5	63.3	49.9	38.3	28.2	19.5	143.0	130.0	123.6	100.9	91.1	86.2	71.1	50.5
6	55.7	43.1	32.3	22.9	15.2	143.0	130.0	123.6	100.9	91.1	86.2	71.1	45.5
7	48.1	36.2	26.2	18.9	13.0	143.0	130.0	123.6	100.9	91.1	86.2	65.6	40.4
8	40.5	30.2	22.7	16.3	10.8	143.0	130.0	123.6	95.1	86.7	82.5	60.1	35.3
9	35.1	26.8	19.7	13.6	8.5	143.0	130.0	123.6	88.5	80.9	77.1	54.6	30.3
10	31.3	23.4	16.7	11.0	6.3	136.9	126.0	120.5	82.0	75.1	71.7	49.1	26.6
11	27.5	19.9	13.6	8.3	....	129.7	119.6	114.5	75.4	69.3	66.2	43.7	24.0
12	23.7	16.5	10.6	....	....	122.5	113.2	108.5	68.9	63.5	60.8	38.2	21.5
13	19.9	13.1	....	....	....	115.3	106.8	102.5	62.4	57.6	55.4	35.5	19.0
14	16.1	....	....	....	....	108.1	100.4	96.5	55.8	51.8	49.9	32.7	16.4
15	....	....	....	....	....	100.9	93.9	90.4	51.8	47.5	45.5	30.0	13.9
16	....	....	....	....	....	93.7	87.5	84.4	48.5	44.6	42.7	27.3	....
17	....	....	....	....	....	86.4	81.1	78.4	45.2	41.7	40.0	24.5	....
18	....	....	....	....	....	79.2	74.7	72.4	42.0	38.8	37.3	21.8	....
19	....	....	....	....	....	74.5	69.2	66.5	38.7	35.9	34.6	19.1	....
20	....	....	....	....	....	70.9	66.0	63.5	35.4	33.0	31.9	16.3	....
21	....	....	....	....	....	67.3	62.8	60.5	32.2	30.1	29.2	..	....
22	....	....	....	....	....	63.7	59.6	57.5	28.9	27.2	26.5	....	....
23	....	....	....	....	....	60.1	56.4	54.4	25.6	24.3	23.7	....	....
24	....	....	....	....	....	56.5	53.2	51.4	22.3	21.4	21.0	....	....
25	....	....	....	....	....	52.9	50.0	48.4	....	....	....	....	....
26	....	....	....	....	....	49.3	46.8	45.4	....	....	....	....	....
27	....	....	....	....	....	45.7	43.6	42.4	....	....	....	....	....
28	....	....	....	....	....	42.1	40.4	39.4	....	....	....	....	....
29	....	....	....	....	....	38.5	37.2	36.4	....	....	....	....	....
30	....	....	....	....	....	34.9	33.9	33.4	....	....	....	....	....

*Allowable fiber stress per square inch, 13,000 pounds for lengths of 60 radii or under, reduced for lengths over 60 radii. Weights do not include details.
†Loads above upper horizontal lines will produce maximum allowable shear in webs. Loads below lower horizontal lines will produce excessive deflections.

section views of a haymow floor for a dairy barn which is shown in Fig. 8. The broken lines from *L* to *M* and *V* to *W* indicate a series of **I** beams which are supported by columns. Columns are represented by the large dots. The floor load will be assumed to be 100 pounds per square foot.

The column at *Y* supports one end each of beams *XY* and *YZ*. Beam
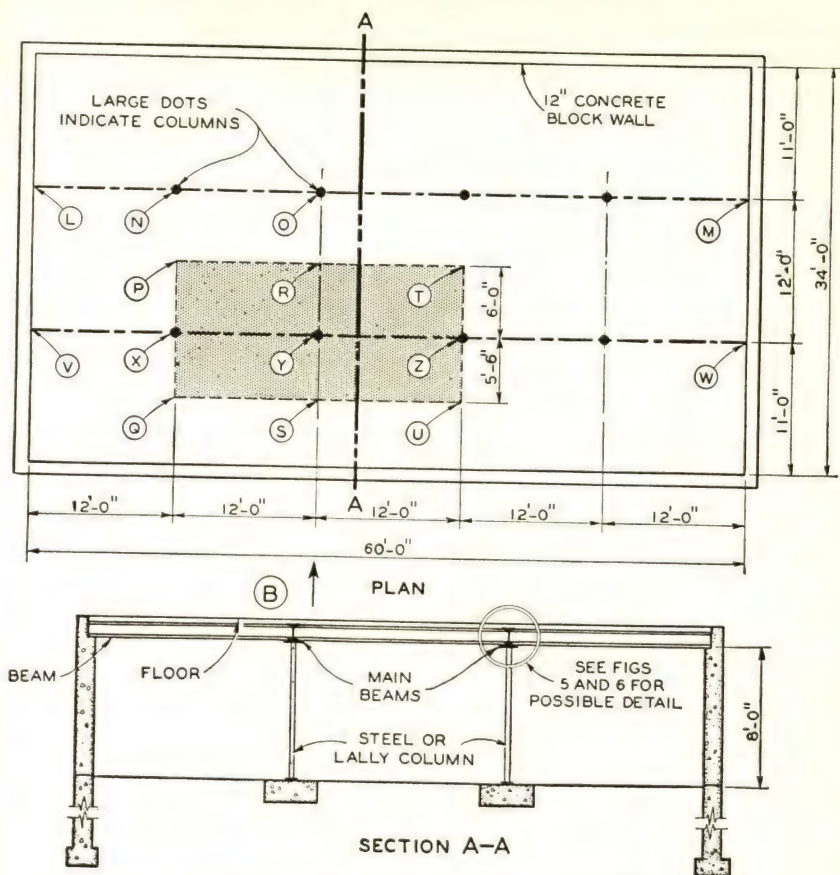
Fig. 8. Columns in a Dairy Barn and the Floor Area They Support

XY supports the floor area halfway to the wall and halfway to the opposite beam indicated as NO. Thus, the floor area supported by this one beam is shown in the plan drawing of Fig. 8 as $PRQS$. The dimensions of this area are 5′ 6″ plus 6′ 0″ or 11′ 6″ wide and 12′ 0″ long. This is an area of 138 square feet. The total weight supported by beam XY is then 138×100, or 13,800 pounds. Beam YZ supports exactly the same load from the area $RTSU$. This total area is represented by the shaded section of the drawing.

If it were possible to stand at point B in Fig. 8 and look toward the series of beams in the line VW, the beams and columns would appear as

shown in Fig. 9. Since Table II deals exclusively with **I** and **H** beams, it will be assumed that the supporting columns shown in Fig. 8 are **I** beams rather than the Lally columns pictured.

Although beams XY and YZ each support 13,800 pounds, the weight from each beam at point Y will be 6,900 pounds, since the weight is uniformly distributed and since column Y supports only half of the weight from each beam. In other words, the load from each beam is equally divided between its two column supports. Therefore, column Y will be supporting 13,800 pounds, or half of the weight carried by each beam. Since the beams themselves have a substantial weight, this figure will be increased to an even 14,000 pounds.
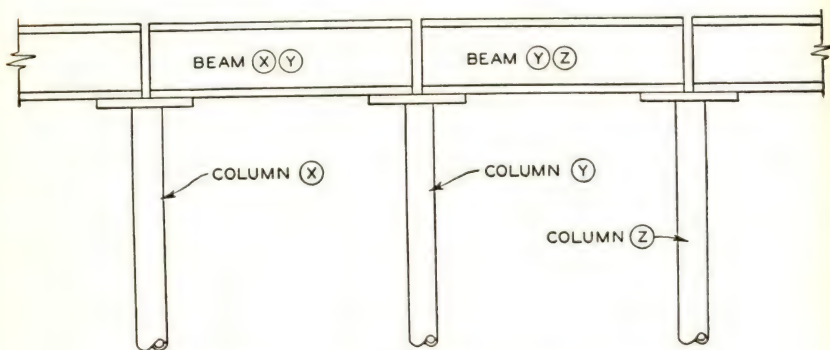
Fig. 9. Details of Beams and Columns Shown in Fig. 8

The height (length) of column Y is 8′ 0″ as shown in the section view of Fig. 8. The correct **I** beam to handle the specific conditions outlined will be found in Table II under the heading, **I** BEAMS.

Since the effective length of the column is 8′0″, the first step in making the beam selection is to locate the beam in the effective length column at the left side of Table II. Reading across the Table from 8, the 16.3 (16,300) pound figure in the fourth column to the right seems to be the figure nearest to 14,000 pounds. However, this figure is *below* the lower horizontal line in that column which means that the 5″ **I** beam at 10 pounds per foot weight is too slender (not an acceptable relationship between length and thickness) to be used for a column 8′ 0″ long, which must support 16,300 pounds. The only figure to the right of 8 which is above the lower horizontal line is the 40.5 (40,500) pound

figure in column one. This indicates that an 8″ I beam would have to be used which weighs 18.4 pounds per foot. This, then, is the column selected for point Y in Fig. 8.

If it were desired to use an **H** beam column at Y instead of an **I**, or the Lally column shown, the procedure would be the same in making the selection. Starting again at 8 in the effective length column, read across to the right until a figure is found under the **H** beam section which comes nearest to the 14,000 pound figure which must be supported. The figure 35.3 (35,300) in the extreme right-hand column means that a 4″ **H** beam will support 35,300 pounds. This figure is above the lower horizontal line indicating that its slenderness ratio is satisfactory.

Lally Columns. The wide use of Lally columns has been mentioned previously. It is likely that such columns would have been used in the dairy barn pictured in Figs. 8 and 9. Assuming Lally columns were specified in the building drawings, it will be necessary to select a column which will be strong enough to support the 14,000 pound weight from beams XY and YZ.

The Lally Company publishes a handbook in which are contained tables of safe loads for columns of different diameters and lengths. The allowable loads for these columns are stated in thousands of pounds which are called *kips*. One of these tables is reproduced as Table III.

The column at Y must support 14,000 pounds as was found from the previous calculations involving **I** and **H** beam columns. The length of the column is still 8′ 0 inches. Referring to Table III, find the column headed by 8 under the general heading of *unbraced length of column in feet*. Directly under the 8 is the figure 32.3 kips, or 32,300 pounds. This is far in excess of the 14,000 pounds of the problem but is the smallest column made and thus will be the one selected for the job.

For this relatively small load a cap without brackets may be used. From Table I it is learned that the g dimension is 3″ and that the base plate will measure 8″ x 8″ x ½ inch.

For further practice in the selection of columns, suppose the haymow floor of Fig. 8 were made of concrete 4″ in thickness, that this floor was supported by I beam joists weighing 18 pounds per foot and I beams weighing 40 pounds per foot, and that the load to be carried by the floor is 200 pounds per square foot. A pictorial view of the I beam, I beam joist, and floor is shown in (A) of Fig. 10. The problem is the

TABLE III. SAFE LOADS FOR LALLY COLUMNS IN KIPS

DIA. OF COLUMN INCHES	WEIGHT PER FOOT LBS.	AREA OF STEEL SQ. IN.	AREA OF CONCRETE SQ. IN.	UNBRACED LENGTH OF COLUMN IN FEET															MAX. LGTH. IN FEET
				6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
3½	15	2.23	7.39	37.9	35.1	32.3	29.4	26.7	24.0	...	...	...	...	...	...	...	...	...	11.64
4	20	2.68	9.89	49.2	46.1	43.1	40.1	37.0	33.9	30.9	27.9	...	...	...	...	...	...	...	13.37
4½	24	3.17	12.73	61.8	58.5	55.3	52.0	48.8	45.5	42.3	39.0	35.8	32.5	...	...	...	...	...	15.10
5	29	3.69	15.95	75.6	72.0	68.6	65.2	61.7	58.2	54.7	51.3	47.8	44.3	40.9	37.4	...	...	...	16.83
5½	36	4.30	20.01	92.1	88.3	84.6	80.8	77.1	73.3	69.6	65.8	62.1	58.3	54.6	50.8	47.1	43.3	...	18.78
6⅝	49	5.58	28.89	128.3	124.2	120.0	115.8	111.7	107.5	103.4	99.2	95.0	90.9	86.7	82.6	78.4	74.2	70.1	22.45
7⅝	64	6.92	38.74	166.0	161.4	156.9	152.3	147.8	143.2	138.6	134.1	129.7	125.0	120.5	115.9	111.4	106.8	102.3	25.92
8⅝	81	8.40	50.03	211.1	206.1	201.1	196.1	191.0	186.0	181.0	175.9	170.9	165.9	160.8	155.8	150.8	145.8	140.7	29.38
9⅝	100	9.97	62.79	259.2	253.8	248.3	242.8	237.4	231.9	226.5	221.0	215.6	210.1	204.6	199.2	193.7	188.3	182.8	32.84
10¾	123	11.91	78.86	319.1	313.1	307.2	301.3	295.4	289.4	283.5	277.6	271.6	265.7	259.7	253.8	247.9	241.9	236.0	36.74
12¾	169	14.58	113.10	421.9	415.4	408.8	402.3	395.8	389.2	382.8	376.2	369.7	363.2	356.7	350.1	343.6	337.1	330.6	43.77

selection of a Lally column of a size necessary to carry this load safely.

In the solution of the first problem, the floor areas involved were found to be 138 square feet each. If concrete weighs approximately 150 pounds per cubic foot and if the floor is 4″ in thickness, each square foot of floor area will weigh 50 pounds, considering the weight of the concrete only. Since $4″ = \frac{1}{3}$ foot, a square foot or 4″ flooring will be equal to $\frac{1}{3}$ cubic foot. The concrete supported by each of the two beams *(XY* and *YZ)* weighs 138×50, or 6,900 pounds. If the produce weighs 200 pounds per square foot, then each beam supports 138×200, or 27,600 pounds of produce. As shown in (B) of Fig. 10, there are four **I** beam joists between X and Y, and Y and Z. Beam XY, for example, supports half of the weight of these joists between itself and the wall and between itself and beam NO. One of the 11′0″ joist beams weighs 18×11, or 198 pounds. The weight of the four of them together between X and Y is 792 pounds but since beam XY supports just half of that weight, the total for these joists will be 396 pounds. One of the 12′0″ joists weighs 18×12, or 216 pounds. Following the same procedure as for the 11′0″ beams, the weight carried by XY will be 432 pounds. Each of the beams then supports 828 pounds of joist weight. The heavy **I** beams weigh 40 pounds per lineal foot. Each beam is 12′0″ in length so each beam weighs 40×12, or 480 pounds. The total weight in pounds supported by each beam is as follows:

Concrete	6,900
Produce	27,600
Joists	828
Beam	480
Total	35,808

Column Y in (B) of Fig. 10 supports just half of the weight carried by beam XY and beam YZ. The combined weight supported by these beams is 71,616 pounds. Therefore, the weight that column Y must support is 35,808 pounds. The floor areas in which this load originates are shown by the shaded section of the plan in (B) of Fig. 10.

Reference to Table III indicates that a Lally column 8′0″ in length must be at least 4″ in diameter in order to support this weight safely.

Reinforced Concrete Columns. The designing and selection of rein-forced concrete columns requires the use of complicated mathematics
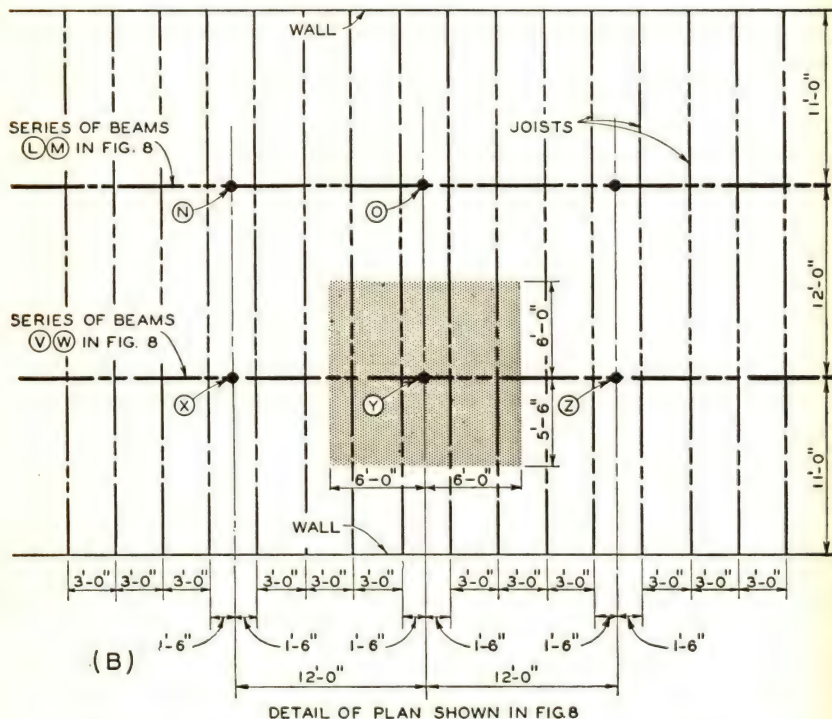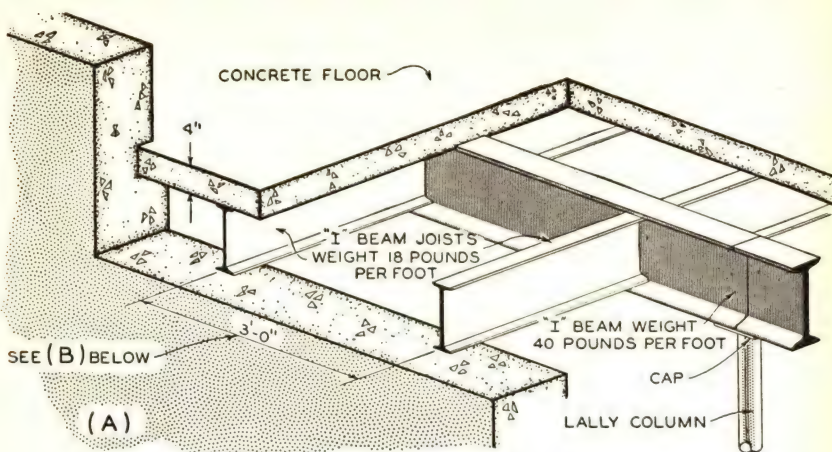
Fig. 10. Detail of Beam, Joists, and Concrete Floor for Dairy Barn Shown in Fig. 8

and other prerequisites beyond the scope of this book. It is recommended, therefore, that a structural engineer be consulted regarding the design or selection of any reinforced concrete columns.

Brick Columns. Brick columns, even when constructed without steel reinforcing bars[2] have a great deal of what engineers call *compressive strength*. In simple terms this means that a brick column can support a great load safely as long as that load is applied straight down and not from one side. For example, note Fig. 11 in which arrows *A*, *B*, and *C* represent loads being applied to a brick column. If the load applied is straight down as indicated by arrow *B*, it will be safely supported if the column is designed and built as will be presently described. However, if there is a tendency for the loads to be applied from either side, as shown by arrows *A* and *C*, a strain is induced which engineers call *bending*. Bending can cause a brick column to fail, so is an important consideration when planning brick columns.

Fig. 11. Application of Loads to a Brick Column

In theory, beams supported by brick columns such as that shown in Fig. 2 across *EG*, transmit their loads straight downward. However, one or more imperfections in the structural work of a building might easily cause the load supported by the column to be applied other than straight down. To avoid any possibility of bending in the column, it is made larger than seems necessary at the time of its design.

If a brick column is part of a brick partition, as in Fig. 2, the partition will have a tendency to strengthen the column against bending. However, it is best to design the column as though it had been intended to stand alone.

When columns receive the loads of beams, their dimensions should be sufficient so that their compressive strength per square inch is not exceeded. Formula (1) is used to determine the required dimensions.

[2]For additional material on reinforced brick masonry, see *Brick Engineering* by Plummer and Reardon, published by the Structural Clay Products Institute.

Formula (1) $A = \dfrac{P}{f}$

A = required area of brick column in square inches

P = load

f = allowable compressive working stress in pounds per square inch

As a means of understanding the application of this formula, it will be assumed that beam EG in Fig. 2 supports 32,000 pounds. The problem will be to determine the size of column G in square inches.

The column supports only half of the beam load or 16,000 pounds since it is an equally distributed load. The City of Chicago building code allows an f value of 200 pounds per square inch when hard-burned bricks and Portland cement mortar are used.

Using formula (1), the first step is to substitute values for the various letters. A trial value for A is selected which, in this first example, is 64 square inches or the area of an 8″ x 8″ column. The value of P is 16,000 pounds. The value of f is 200 pounds. Then:

$$64 = \frac{16,000}{200}$$

$$64 = 80$$

This shows that the 8″ x 8″ column is not large enough because area A has to be at least equal to the 80. Using 144 square inches, or a 12″ x 12″ column, gives:

$$144 = 80$$

The 144 square inch area is greater than the 80 so a 12″ x 12″ column is actually stronger than necessary. This additional strength will increase the resistance to bending. The column will have a satisfactory safety factor and is the one which should be selected for the job. In the case of column G in Fig. 2, the brick partitions on either side of the column will further increase the column's resistance to bending, all of which makes for good design.

If brick columns are used in cases such as illustrated in Fig. 1, the design is developed just as was explained for the preceding problem.

Brick pilasters are used in order to provide increased bearing surface for heavy beam ends and must be designed to share whatever part of the beam load is thought necessary. If the beam at C in Fig. 1 sup-

ports a load of 18,000 pounds, half of this load or 9,000 pounds will be transmitted to the foundation. A pilaster normally would be expected to carry half of this load, or 4,500 pounds. The process involved in designing such a pilaster is as follows:

A trial size for the pilaster is selected first. If the dimensions of this pilaster are 4″ x 8″, the value of A is 4×8, or 32 square inches. Substituting values for the various letters in formula (1) it is seen that P is 4,500 and f is 200.

$$32 = \frac{4,500}{200}$$

$$32 = \text{approximately 23}$$

Thus, the 4″ x 8″ brick pilaster is stronger than is actually necessary and will be adequate to handle the job.

A further precaution in the design and erection of brick columns is the strict observance of the height-diameter relationship. The height of

16″ X 24″ COLUMN OR PILASTER CONSTRUCTION IN 8″ CONCRETE MASONRY WALL

(A)

FILL CORES WITH CONCRETE

COLUMN CONSTRUCTION USING 8″ X 8″ X 16″ UNITS

(B)
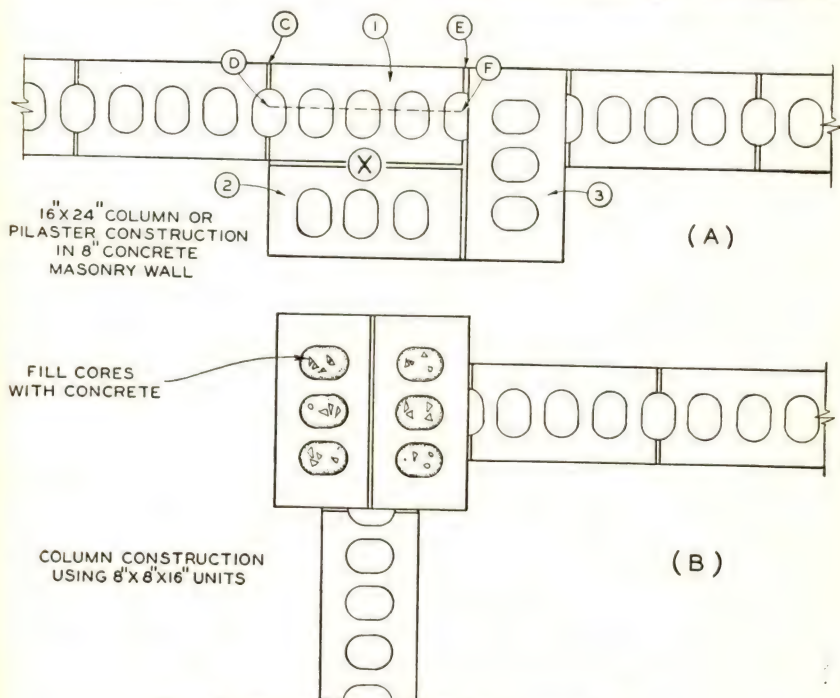
Fig. 12. Sections of Concrete Block Columns or Pilasters

a brick column should never be greater than ten times its least dimension. In other words, a 12″ x 12″ column should not be over 10′0″ in height.

Concrete Block Columns. The design of concrete block columns depends to some extent upon the shapes of the blocks. Fig. 12 shows two examples of the concrete block column and pilaster. The column or pilaster at (A) could have been used at E in Fig. 2 if the foundation had been built of concrete blocks. The column shown at (B) in Fig. 12 could have been used at G in Fig. 2 had the partition been built of concrete blocks instead of bricks.

The compressive strength of concrete block columns is just as important as it was for columns built of bricks. These strengths are figured in the same way described for brick columns and the formula is the same. As a means of checking through the formula once again, assume the foundations and partitions shown in Fig. 2 were to be built of 8″ x 8″ x 16″ concrete blocks and that beam EG must support 32,000 pounds.

The column or pilaster design at (A) in Fig. 12 will be used as a first trial. The value of A in formula (1) is 16×24, or 384. The value of P is 16,000 and the value of f, according to most building codes where Portland cement mortar is used, is 80. Substituting values for the various letters it is seen that

$$384 = \frac{16,000}{80}$$

$$384 = 200$$

This shows that the 16″ x 24″ column or pilaster is larger than necessary. If blocks 1 and 2 only are used the area will be 16×16, or 256 square inches. Then

$$256 = \frac{16,000}{80}$$

$$256 = 200$$

This is much better since the area obtained is more nearly the area required. Blocks 1 and 2 may be used safely.

As a final problem illustrating the use of this formula in conjunction with concrete blocks, assume it is desired to design a concrete block col-

umn to be used at G in Fig. 2. The load is the same as in the preceding example so it will be safe to use a column built of two blocks as shown in (B) of Fig. 12. Filling the holes of the blocks with a 1:2:4 mix concrete will add greatly to the strength of such columns and will make them more stable. This is a practice which is highly recommended.

The figures 200 and 80 used in the foregoing examples are those specified in most building codes. Such codes limit these figures to allow for an ample factor of safety. For example, for concrete blocks the compressive strength is more nearly 700 pounds per square inch. The codes limit the loading to 80 in order to provide an ample factor of safety. This factor of safety makes certain that there will be no structural failures due to overloading, unexpected loads, variation in materials and workmanship, and other variables.

Wood Columns. As shown by the supports at D and E in Fig. 1, wood columns often support beam ends in small structures such as residences and barns. The total load supported by a wood column is calculated in the same manner as described for steel and Lally columns.

The tendency for wood columns to bow out under heavy loads has been mentioned previously. A column of a given size, such as an 8 x 8, is capable of supporting less and less load as its length becomes greater. The load that such a column can support without bowing or buckling depends upon the relationship between the length (or height) of the column in inches (which is known as l) and its smallest width or thickness (which is known as d). This is expressed as $\frac{l}{d}$ or l divided by d.

An 8 x 8 column is actually only about 7½ x 7½ because of the way such lumber is planed at the mill. For a 7½ x 7½ column that is 8′0″ in length, the value of l is 96″ and the value of d is 7½ inches. Therefore , $\frac{l}{d}$ equals $\frac{96}{7\frac{1}{2}}$, or 12.8. Values of $\frac{l}{d}$ greater than 50 are not generally permitted in building codes since they are considered unsafe.

Once the value for $\frac{l}{d}$ for any column has been determined and found to be within the limits of safe practice, the next step in the design of wood columns is the consideration of area and stress.

The actual cross-sectional area of an 8 x 8 column (actually 7½ x 7½) is 7½ × 7½, or 56¼ square inches. The safe load-carrying capacity is its area multiplied by the safe stress in pounds per square

inch and is known as f. This will be called formula (2) and is expressed as follows:

Formula (2)   Safe load $= A \times f$

$A =$ area in cross section of column

$f =$ safe stress in pounds per square inch

The method for finding the value of f is formula (3) and is as follows:

Formula (3) $f = C \left(1 - \dfrac{\dfrac{l}{d}}{80} \right)$

In this formula, C is the safe loading in pounds per square inch for short blocks of the kind of wood to be used. The value of C has been determined by experiment to be 1,100 pounds for Douglas fir and southern pine while it is only 700 pounds for weaker woods like Norway or white pine and spruce.

To solve formula (2) it is necessary first to solve formula (3) in order to find the value of f. The procedure is easy and should cause no trouble.

It has already been determined that $\dfrac{l}{d}$ has a value of 12.8. This value is substituted in formula (3) in place of the $\dfrac{l}{d}$ and the formula becomes:

$$f = C \left(1 - \frac{12.8}{80} \right)$$

Next, divide 12.8 by 80. The result is .16. Substituting .16 in place of the fraction, the formula is:

$$f = C \ (1 - .16)$$

If .16 (sixteen hundredths) is subtracted from 1, the answer is .84. In other words, to subtract .16 from 1, write it this way:

$$\begin{array}{r} 1.00 \\ - \ .16 \\ \hline .84 \end{array}$$

Substitute the .84 in place of the $1 - .16$ and the formula becomes:

$$f = C \ (.84)$$

As the formula now stands, it means that f equals $1{,}100 \times .84$. Thus:

$$f = 924$$

Now that the value of f is known, formula (2) can be solved. The A of formula (2) stands for the cross section of the column which has already been calculated as 56¼ or 56.25 square inches. Then $A \times f$ is the same as 56.25×924, or 51,975 pounds. This is the safe load an 8 x 8 column 8' 0" long can support safely.

Table IV gives the safe loads in pounds for columns of hardwoods such as Douglas fir or southern pine and for columns of softwoods such as spruce. Three different sized columns with three different lengths are shown in each wood classification.

TABLE IV. SAFE LOADS IN POUNDS FOR WOOD COLUMNS

Height, Feet	Hardwood Size, Inches			Softwood Size, Inches		
	5½ x 5½	7½ x 7½	9½ x 9½	5½ x 5½	7½ x 7½	9½ x 9½
8....	26,000	52,000	87,000	19,000	38,000	63,000
10....	24,000	49,000	84,000	18,000	36,000	61,000
12....	22,000	47,000	80,000	16,000	34,000	58,000

There is another method for finding the value of the safe load in pounds per square inch which may be supported by wood columns of different sizes, lengths, and of various kinds of wood. The safe load per square inch depends upon the answer obtained by dividing the length of the post in inches by its least dimension. As calculated before, this would be $\frac{l}{d}$ and in the case of the 7½" x 7½" x 8' 0" column is 12.8. Table V gives the safe load in pounds per square inch to be used in conjunction with this formula. Two different grades and ten different kinds of wood are represented, with values of the term $\frac{l}{d}$ ranging from 10 to 50. "Common Structural Grade" is the quality of lumber used for most buildings. For lumber of this grade with an $\frac{l}{d}$ value of 12.8, the safe stress in pounds per square inch would be found in the second column from the right in Table V, headed 12 (see arrow). The safe stress in pounds per square inch for Douglas fir, Coast Region would be 870 (see box) pounds per square inch. This compares favorably with the 924 obtained by the use of formulas (2) and (3). Thus, either method is satisfactory.

As a means of checking these formulas and tables, assume it is desired to determine the size and length of the two wood columns D and E in Fig. 1. Beams A, B, and C each support 13,000 pounds, are 8 x 10 in size, and are built up.

TABLE V. WORKING STRESSES* FOR POSTS AND TIMBERS 6″ x 6″ AND LARGER†
IN POUNDS PER SQUARE INCH

Recommended by Forest Products Laboratory, United States Forest Service

SELECT STRUCTURAL GRADE

Species	Ratio of Length to Least Dimension l/d ↓										
	10	12	14	16	18	20	25	30	35	40	50
Cedar, western red..........	700	686	674	656	629	592	438	304	224	171	110
Douglas fir, Coast Region...	1175	1149	1127	1093	1045	975	702	487	358	274	175
Dense....................	1285	1251	1222	1176	1112	1022	702	487	358	274	175
Rocky Mountain Region ..	800	786	774	753	726	688	526	365	268	206	132
Hemlock, West Coast.......	900	885	872	852	823	783	614	426	313	240	153
Larch, western.............	1100	1068	1041	999	937	851	570	396	291	223	142
Pine, southern, dense.......	1285	1251	1222	1176	1112	1022	702	487	358	274	175
Redwood..................	1000	972	947	910	856	781	526	365	268	206	132
Spruce, red, white, Sitka	800	786	774	753	726	688	526	365	268	206	132

COMMON STRUCTURAL GRADE

Species											
Cedar, western red	560	553	547	538	524	505	425	304	224	171	110
Douglas fir, Coast Region ...	880	870	861	847	826	796	675	487	358	274	175
Dense....................	1025	1017	996	965	935	893	698	487	358	274	175
Rocky Mountain Region..	640	632	627	617	602	582	500	365	268	206	132
Hemlock, West Coast.......	720	712	706	696	680	660	573	426	313	240	153
Larch, western.............	880	863	849	828	798	752	570	396	291	223	142
Pine, southern.............	880	870	861	847	826	796	675	487	358	274	175
Dense....................	1025	1017	996	965	935	893	698	487	358	274	175
Redwood..................	800	786	773	754	726	688	526	365	268	206	132
Spruce, red, white, Sitka....	640	632	627	617	602	582	500	365	268	206	132

NOTE: For continuously dry select structural and common structural grade. Examples given with basic provisions for structural grades of American lumber standards. Compression parallel to grain.

*These working stresses have been adopted by the Building Code Committee of the U.S. Department of Commerce, and by the American Railway Association, and are printed for information by the American Society for Testing Materials.

†These values may be applied to material smaller than 6″ x 6″ by limiting the size of knots to the proportion of width of face permitted on a 6″ face.

Courtesy of West Coast Lumbermen's Association

The first step in solving a problem of this kind is to find the length (or height) of the column. Ordinarily, architects show the distance from the basement floor to the surface of the first floor on all blueprints for residences and other small buildings. Since columns rest on footings which are 4″ below the surface of the basement floor (the thickness of the average basement floor), this dimension must be added to the length of such wood columns. The thickness of the flooring (single or double) of the first floor, the depth of the joists, and the depth of the beam and cap must all be added together and the answer subtracted from the floor-to-floor dimension. By this process the exact length

(height) of the column can be determined. The floor-to-floor dimension should be designed with the thought in mind that lumber is supplied in lengths which are multiples of two feet. If this planning is done carefully, little or no waste of expensive, large-size lumber will occur. For example, it would be wasteful if, because of the floor-to-floor dimension, a column 8′ 5″ were required. A 10′ 0″ length of lumber would have to be purchased and 1′ 7″ sawed from one end in order to get the right length. The material sawed off would be waste unless it could be used for beam caps.

A practical column length is 7′ 9 inches. Lumber 8′ 0″ in length can be purchased with but 3″ of waste in each column. When possible, the small dimension of the column should be the same width as the beam it supports. In this particular case the beam is 8″ wide so an 8 x 8 column should be considered for use.

The first step is to determine the $\frac{l}{d}$ relationship of the 8″ x 8″ x 7′ 9″ column chosen. Converting the 7′ 9″ dimension to inches gives $\frac{93}{7\frac{1}{2}}$ (remember that an 8 x 8 piece of lumber is actually 7½″ x 7½ inches) or 12.4 which is well below the objectionable 50.

If the use of southern pine is assumed, formulas (2) and (3) can be solved. Remember that formula (3) must be solved before formula (2) can be solved.

$$f = C\left(1 - \frac{\frac{l}{d}}{80}\right)$$

$$f = C\left(1 - \frac{12.4}{80}\right)$$

$$f = C\,(1 - .155)$$

$$f = C\,(.845)$$

$$f = 1,100\,(.845)$$

$$f = 929$$

Solving formula (2), the area of the column cross section is 56.25 square inches. The safe load a column can support is $A \times f$. Multiplying 56.25 by 929 gives 52,256 pounds which is the maximum safe load a column 8″ x 8″ x 7′ 9″ of southern pine is capable of supporting.

If beams *A*, *B*, and *C* each support 13,000 pounds, columns *D* and *E* will have to carry half the load from each beam they help support. This will be 13,000 pounds per column. The column under consideration is much stronger than necessary but will be used because its least dimension is equal to the width of the beam.

These problems serve to illustrate the fact that a piece of wood is much stronger in a vertical position than when it is horizontal.

HOW TO PLACE COLUMNS

The method for determining the correct level for column footing tops is described in Chapter II.

Steel Columns. When **I** beams or **H** beams are used as columns, they should, if possible, be fabricated by the manufacturer according to the builder's specifications. Angles, shown in Fig. 5, should be welded or riveted on. The bottom plate should be set on a bed of fresh 1:3 Portland cement mortar and leveled by the use of a mason's plumb rule or level. Unless bolt heads are countersunk on the under side of the bottom plate, small, shallow holes must be chipped out of the concrete to accommodate them. It should be remembered that the thickness of the mortar bed must be considered when determining the length of the column.

After the base plate has been set, allow at least two or three days for the mortar to become hard before bolting the column to the plate. Once the column is in place it should be checked with a level to insure its being perfectly perpendicular.

If, during subsequent construction, the column proves to be too long, the footing must be chipped to the required depth or an entirely new footing prepared and the plate reset.

Lally Columns. Lally columns are equipped with builder-specified caps when delivered. The bases come separately and are set in a bed of fresh 1:2 Portland cement mortar. Before the cement mortar has a chance to set, the base is trued up with a level. After two or three days the column can be bolted to the base plate, after which the beams can be placed in position and bolted to the caps.

Reinforced Concrete Columns. This type of column requires a concrete mix as explained for reinforced concrete beams in Chapter IV. Reinforcing bars must be placed and wired in the formwork so that

every rod is the correct distance from the forms. This makes certain that the reinforcing rods will be the required distance from the surface of the concrete. All of the concrete for any one column should be placed at one time so that no part of the column will harden separately. The concrete should be placed in the forms slowly. It should be spaded thoroughly along the surface of the forms.

Form removal time is about the same as that described for beams and lintels in Chapter IV.

Brick Columns. Brick columns can be built easily to the right height by varying slightly a number of the mortar joints. The exact height above footings should be determined first and the masonry work then laid up accordingly.

When brick columns are to support wood beams, some means must be found to secure them in place. One method is to build anchor bolts into the masonry work, leaving enough of the bolt extending so that it will go through a hole in the beam and allow a washer and nut to be screwed on. An alternate method is to provide a channel about two inches in depth at the top of the column into which the beams could fit and be held in place.

When steel beams are to be supported, a steel or wrought iron plate is provided.

Concrete Block Columns. The footing level and the number of courses in concrete block columns must be planned so that the beams supported will be at the correct joist height. The thickness of the mortar joint (¼″) is automatically taken care of because of the actual size of the block. Its dimensions, 7¾″ x 8″ x 15¾″, are planned so that with ¼″ mortar joints, the blocks measure exactly 8″ x 8″ x 16 inches. If the exact height for beam bearing surfaces cannot be obtained with concrete blocks, concrete or clay bricks can be used to build up to the exact height required above the top block. Solid concrete blocks measuring 8″ x 3″ or 4″ x 16″ and 8″ in height also can be used.

In the case of a column or a pilaster such as at (A) in Fig. 12, building the beam bearing surface to the correct height may have to be done in the same manner as explained for columns.

Wood beams are secured in place by means of bolts or channels as described for columns built of bricks.

When a beam end rests on a column or pilaster such as shown at

(A) in Fig. 12, the beam should rest at the point marked X and should not extended beyond line DF. A piece of concrete block 4″ x 8″ x 16″ can be used as trim to fill the space $DCEF$.

If steel beams are supported by concrete block columns, a steel or wrought iron plate is used as a cap to keep the beam from cutting into the masonry work. The beam should be bolted to the plate.

Wood Columns. When wood columns are to be used, the tops of the footings should be made rather smooth and perfectly level. The columns then rest on the footings with no further fitting. The concrete floor which is poured around the base of the column will serve to keep it in place.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. Why it is almost impossible to make textbook recommendations for the kinds of columns to use generally?

Answer. Because of the many varying factors relative to costs, availability, locations, and other conditions.

2. What type of column is most generally used and why?

Answer. The Lally column because of the ease with which it is installed and its great adaptability for so many conditions.

3. What concrete mix is used in the manufacture of Lally columns?

Answer. $1 : 1\frac{1}{2} : 3$.

4. What size standard steel base should be used with a 5″ Lally column?

Answer. $10″$ x $10″$ x $\frac{3}{4}″$.

5. Under what conditions the flanged type of Lally column caps are used?

Answer. Where heavy loads are to be supported.

6. How parts of a concrete block foundation can be strengthened without enlarging it?

Answer. By filling the holes in the blocks with concrete.

7. Why it is safe to set wood columns directly on the footings without any anchorage?

Answer. Because the concrete floor is poured after the column has been set, thus keeping it in place.

8. Which is more suitable for columns—hardwoods or softwoods and why?

Answer. Hardwood because it is so much stronger.

9. What is the greatest value of $\frac{l}{d}$ allowed for wood columns?

Answer. 50.

10. What the effective length of a beam is?

Answer. The distance from the bottom of the column to the under side of the beam it supports.

11. What the unbraced length of a column is?

Answer. It is the same as the effective length.

12. What the unbraced length of a brick column is when it is built as part of a partition?

Answer. There is no unbraced length because the partition helps to brace the column.

13. How many pounds a *kip* represents?

Answer. 1,000.

14. How many pounds a square foot of concrete wall 6" thick will weigh?

Answer. 75 pounds.

15. If it is advisable to include the weights of beams in floor load calculations?

Answer. Because beam weights may amount to several hundreds of pounds, it is advisable to include them in floor load calculations.

16. What the actual size is of an 8" x 8" piece of lumber?

Answer. $7\frac{1}{2}"$ x $7\frac{1}{2}"$.

17. What the allowable C value is for Douglas fir?

Answer. 1,100 pounds.

REVIEW QUESTIONS

1. What is a concentrated load?
2. What is meant by bending?
3. What is the procedure for designing a brick column?
4. Why are brick columns designed considerably larger than necessary from the load standpoint?
5. What does $\dfrac{l}{d}$ mean?
6. How is this formula used in designing a wood column?
7. Why must wood beams be rather short?
8. Where might long and deep beams be used without much regard for their depth?
9. Why are steel or wrought iron plates used at column tops when steel beams are to be supported?
10. How is the base for a Lally column set?
11. What is a uniformly distributed load?
12. How much does a 4" brick wall weigh a square foot?
13. How much does concrete weigh a cubic foot?
14. Why is a thin, brick pilaster sometimes used next to the foundation under a beam end?
15. What thickness for mortar joints is recommended for use with concrete blocks?
16. Which is better, a thin or a thick mortar joint?
17. What is an equally distributed load?

CHAPTER VI

Chimneys and Their Construction

QUESTIONS CHAPTER VI WILL ANSWER FOR YOU
1. *What are the functions and requirements of a chimney?*
2. *What are the components of a chimney and what effect does each have on its operation?*
3. *What are the most common of the acceptable materials for use in building chimneys and how are they used?*
4. *What are the various kinds of chimneys and what determines their design from the standpoints of utility and appearance?*
5. *What are the precautions to be observed in the building of chimneys?*

INTRODUCTION TO CHAPTER VI

The need for chimneys in man's dwellings dates back to the discovery of fire. Once primitive man had learned to control and apply this great gift, the need for a method of carrying off the products of combustion became evident. It is not difficult to imagine the living conditions as they must have been during the period of cave dwelling. Unless a natural flue or other means of ventilation existed as the result of the formation of the cave, fires during cold weather must have produced intolerable conditions, leaving to the occupants a choice of asphyxiation or freezing.

Conditions could not have been much better long after man had progressed to the stage of housebuilding. For centuries, fires for light and warmth were confined to braziers or possibly merely an unused corner of a room. The smoke escaped through a hole which was left in the roof, and it may be assumed that an appreciable quantity of rain and snow found its way in by the same hole during inclement weather.

About the twelfth century the people of northern Europe abandoned the brazier and hole-in-the-roof idea for a fluelike passageway in the wall leading to the outside from a fireplace by the wall. One of the oldest examples of this rudimentary flue can be seen in the kitchen of the Abbey of Fontevrault, France.

During the thirteenth and fourteenth centuries the flue developed from a round conduit of stone with a conical cap to a more specific architectural form. By the end of the fifteenth century the general practice was to use a number of fireplaces, grouping the flues from these in a vertical, usually rectangular mass of masonry. This structure in turn was carried well above the roof and was usually decorated. In France in the latter half of this century, this decoration was extremely lavish. In the chateaux of the Francis I period, it competed with the dormers in the extent to which the decoration was carried out.

Entablatures, heraldic ornaments, and pilasters were used profusely. In England this decorative effect was obtained by grouping the flue tops as independent features made of brick and set on a stone base. Each flue was then treated as a separate shaft with a base and a cap and was polygonal or twisted in shape. In the early Renaissance, flues were sometimes treated like classic columns; but with the development of classicism, the chimney became simple again—a mere rectangular mass of masonry. In the Italian Renaissance, the chimney was merely utilitarian and whenever possible, was hidden.

In American Colonial architecture the chimney was either a large square mass in the center of the roof or else was developed as an important feature of the end gable walls. To a large extent present-day architecture follows this general trend. The wide use of central heating in a country where fires are required from five to six months of the year makes the chimney an important feature of the structure. Since it is an essential part of the building, it is treated in as artistic a manner as possible and frequently forms the dominant characteristic in the design of the house.

This chapter describes the functions of a chimney and outlines the methods of design and construction necessary to achieve proper operation at all times. It becomes obvious once the text has been read that a chimney is worthless if it does not perform the services required of it. Features influencing design and construction such as grate size, flue size, selection of materials, effects of altitude, the influence of near-by buildings, and chimney height are but a few of the many critical points discussed in this chapter.

REQUIREMENTS OF CHIMNEYS

The design and erection of common chimneys for residences and other small buildings require careful consideration of a surprisingly large number of details. These details are all important to the proper functioning, safety, and durability of the chimney. A poorly designed and built chimney greatly reduces the efficiency of an otherwise excellent heating system. It will cause fireplaces to operate in an unsatisfactory manner. It will also require frequent cleaning and will constitute a fire hazard. Such a chimney will be a constant source of annoyance and expense. On the other hand, well-designed and properly constructed chimneys efficiently serve their purpose and require but little attention. The design of simple chimneys is not difficult nor is their erection beyond the average mason's skill provided the necessary details are understood. This chapter explains the theory of chimneys, describes the common kinds of chimneys, and tells how they should be designed and erected. These are the important points which should be known concerning chimneys. If these features are thoroughly understood, no difficulty should be experienced when they are encountered.

THEORY OF CHIMNEYS

Purpose of Chimneys. In general, chimneys have two main purposes. Everyone is familiar with the chimney as the outlet in a structure through which are carried away fumes and other unconsumed gases (smoke) resulting from the combustion of all types of fuels. Unless

Fig. 1. Chimney Used as a Decoration
Courtesy of Dr. Russell M. Anderson

they are disposed of properly, such fumes and gases are injurious to the health of occupants of buildings and in addition constitute a fire hazard. These fumes must be carried off in such a way as to provide insulation for the structural parts of the building against fire and high enough to be dissipated harmlessly into wind and air. Few people, however, are familiar with a second important function of the chimney. It serves to create a *draft*.

In addition to these two main purposes of the chimney, there are

secondary considerations concerning ornamentation and structural support. In many cases, and especially in residences, chimneys form a part of the artistic design. Occasionally they are the principal feature
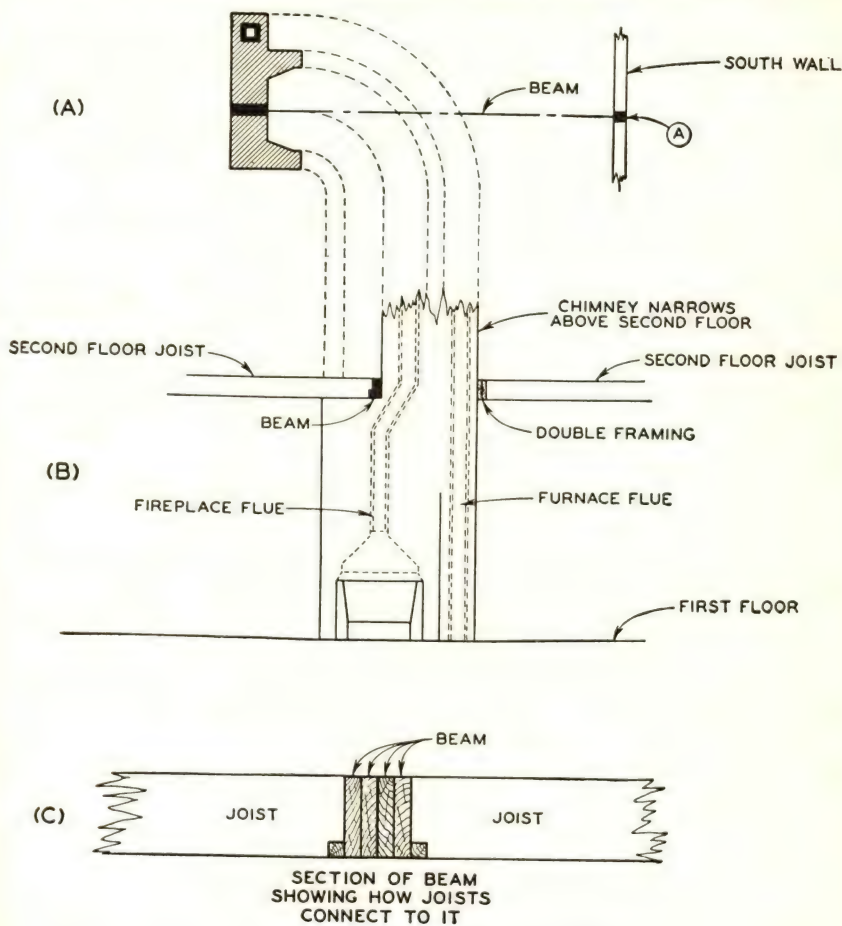
Fig. 2. Chimney Used as a Structural Support

of that design. For example, study Fig. 1. The chimney in this residence is definitely the central feature of the design. Fig. 2 shows how the chimney can be used to support structural members in a building. In (A) of this illustration the plan view is given showing a beam, one end of which is supported by the chimney, the other end by the south
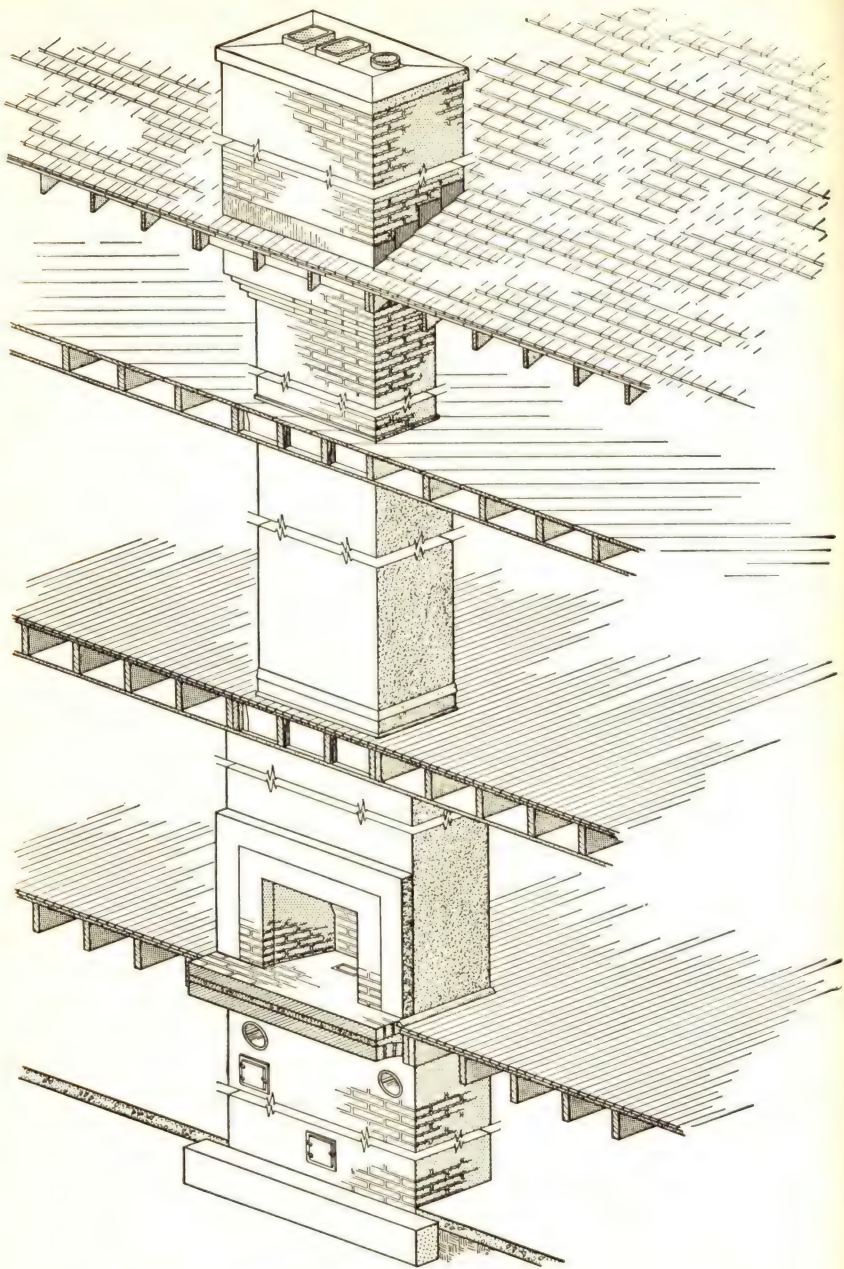
Fig. 3. Pictorial View of a Three-Flue Chimney with Fireplace

wall at A. The elevation view is shown at (B) wherein one end of the supported beam can be seen. At (C) is shown a section of the beam.

Chimney Components. Fig. 3 shows a pictorial view of a typical chimney. It extends from the basement of the residence up to and beyond the roof. Fig. 4 illustrates the plan, elevation, and section views of the same chimney. If these drawings are studied carefully, the principal parts of the typical chimney can be learned. This particular chimney was designed to serve a fireplace, furnace, and gas water heater. The elevation and section views show the fireplace at the first floor level. The elevation view shows the intakes or openings for pipes from the furnace and water heater in the basement. It also shows the ashpit and the ash cleanout doors in the basement for the fireplace. Note that in the elevation view there are parallel vertical lines composed of short dashes which extend over the furnace and water heater intakes and above the fireplace. These are the flues which carry off the fumes and the gases. In the section view, the fireplace flue between the top of the fireplace and the top of the chimney is shown by a solid line.

The plan view in Fig. 4 shows flues which are marked *1*, *2*, and *3*. These numbers correspond to the same numbers in the elevation view. The chimney, as shown in Figs. 3 and 4, is topped with a concrete cap and a cement wash.

The flues are surrounded with brickwork which is called the chimney walls. These walls hold the flues in place and constitute the structural work of the chimney. The entire chimney is supported by a concrete footing which is necessary to prevent settlement and cracks.

DRAFT. Satisfactory operation of all kinds of heating plants, including fireplaces and ranges, depends on ample draft in the flues of the chimney. A draft accomplishes two objectives. First, it carries away the fumes and gases. Second, and more important, it provides a constant supply of fresh air which is necessary to keep fires burning at proper rates. The draft is created as the hot fumes and gases, which are lighter than air, seek a higher level. They rise from the fireplace or furnace into the flues. The higher they go, the faster their rate of ascent becomes. This column of rising gas and heated air causes a suction at the bottom of the fireplace or furnace. This suction causes air to be drawn through the fuel beds in the fireplace or furnace which
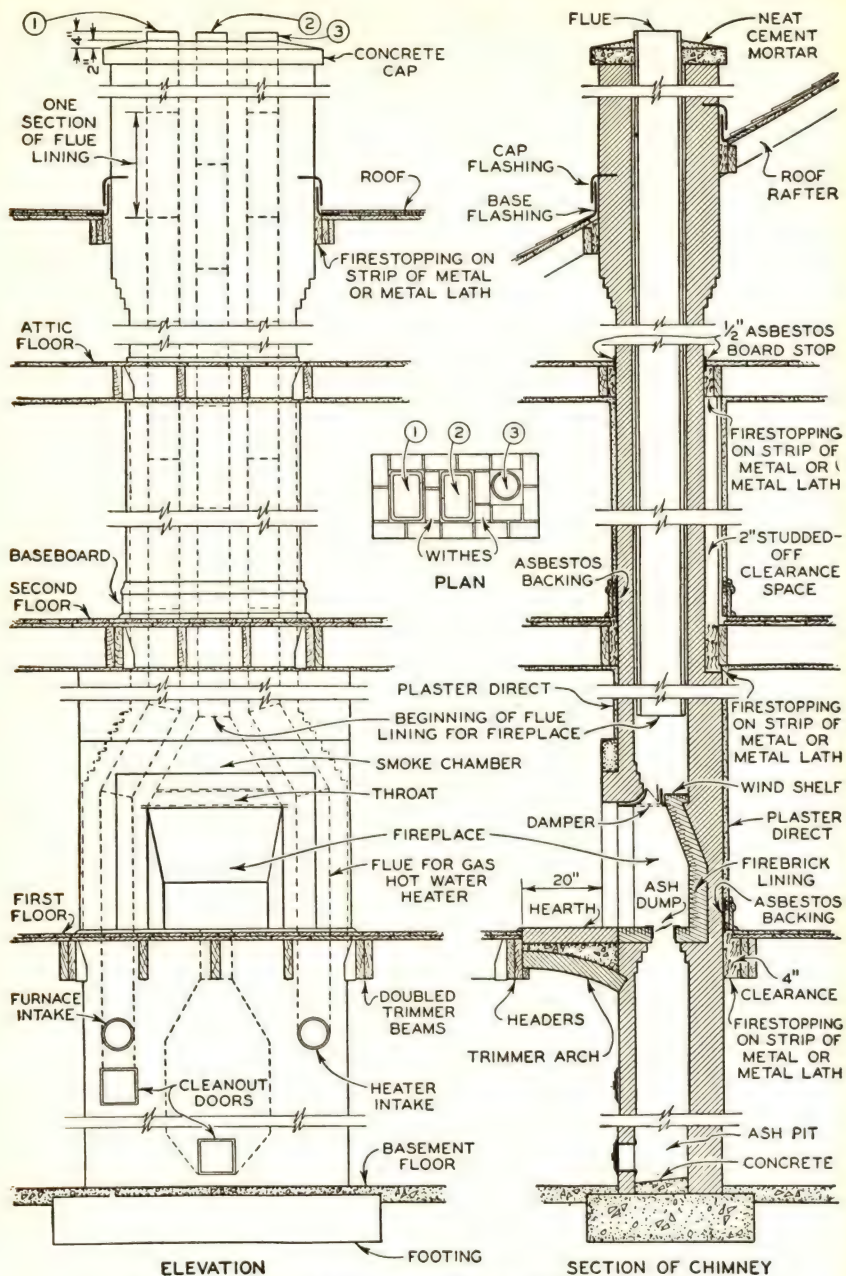
Fig. 4. Elevation and Sectional Views of Chimney Shown in Fig. 3

in turn makes the fire burn at the desired rate. For this reason, chimneys must have certain minimum heights. Factors governing these minimum heights are discussed more fully in the pages that follow.

FLUES. Chimney flues can be formed of the bricks or other material which has been used for the chimney walls as shown in Fig. 5. Flues also can be lined with rectangular or round flue linings of fire clay as illustrated in Fig. 6.

A chimney which has been erected without flue linings such as was shown in Fig. 5 cannot be depended upon for any length of time. The unlined flue is rough and therefore tends to gather soot. This accumulation of soot in time becomes so great that the flue area is considerably reduced, preventing adequate draft. Brickwork and
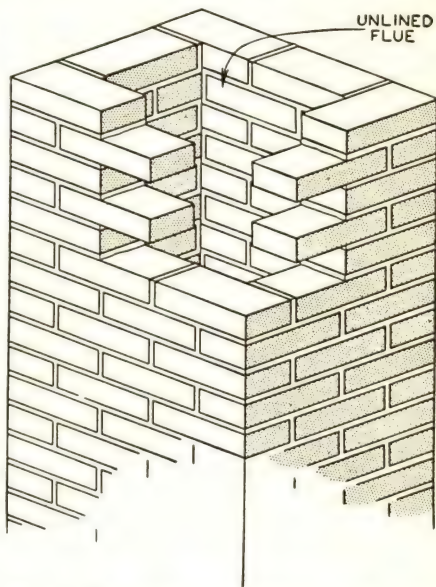
Fig. 5. Typical, Small Chimney with One Unlined Flue

mortar disintegrate when exposed to the action of fuel gases. This disintegration, combined with that occurring naturally from changes in temperature, frequently will cause cracks in the masonry, thereby reducing the effectiveness of the draft. The accumulation of soot in flues is a fire hazard since it is always subject to burning. If there are cracks or loose mortar in the chimney, the fire can easily attack surrounding structural parts and cause serious damage. Many roof fires are caused in this manner. Because an unlined flue is rough, it also has a tendency to reduce the effectiveness of the draft, since the fumes and gases are subject to friction or resistance. A flue lining should always be used when building a chimney but if for any reason one is not used, the walls of the chimney should be made 8″ in thickness instead of 4″ as was shown in Fig. 5. The increased thickness of the wall will eliminate the crack and fire hazard to some extent.

Flue linings should always be used for chimneys serving gas-fired

heating appliances. These linings should be in the form of fire clay liners such as shown in Fig. 6 or of brick made from fire clay. The products of combustion from gas burners contain a large volume of water vapor and some acids. These condense on the inside walls of the flues because of the comparatively low temperature of the masonry. The penetration of this moisture and acid may cause efflorescence and discoloration. As a result, mortar joints will deteriorate rapidly. A good flue lining of fire clay will stop such penetration.
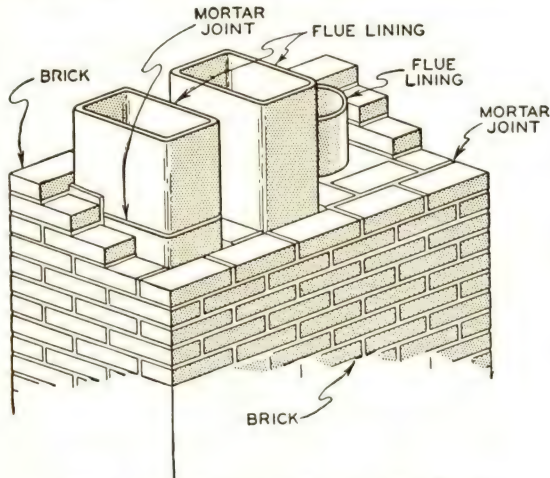
Fig. 6. Large Chimney with Three Lined Flues

Chimneys with lined flues such as shown in Fig. 6 are far superior to those with unlined flues. The cost of flue lining is not great, since, when it is used, the chimney walls need be only 4″ in thickness, except near the top, instead of 8 inches. Lined flues are smooth. Because of this, they will not accumulate soot and are thus not a fire hazard. The elimination of the danger from fire alone makes them worth while. The building laws of most cities and towns require linings for all types of chimneys.

Flues should be built as straight as possible. However, it is sometimes necessary to build them with what is called an *offset*, as shown in Figs. 33 and 35. Since offsets make the flues turn at an angle for some distance before straightening out, they greatly increase the friction, have a tendency to collect soot, and generally decrease the draft.

If offsets are necessary, as sometimes happens, especially in the chimneys of residences (see Figs. 3 and 4), their slope should not exceed 30° from the vertical and the full area of the flue should be maintained throughout.

Round flues are more efficient than rectangular ones because the fumes and gases ascend in a spiral. Thus, the products of combustion meet with less friction in a round flue than in a rectangular one. A rectangular flue is not effective over its full transverse area. The column of rising fumes and gases, being nearly circular in cross section, does not fill the corners. However, rectangular flues are cheaper to build and therefore are more generally used. They are better suited to brickwork and require less erection time.

CHIMNEY MATERIALS. Chimney walls may be built of brick, stone, or solid concrete masonry units. Flue linings should be made of fire clay if at all possible.

Brick. A good, hard-burned, common brick is suitable for brick chimneys. However, for parts of the chimney which are visible, face brick should be used for exterior courses. For chimneys not having a regular flue lining, fire-clay bricks should be used to build the flues providing such bricks are available. Firebrick resist heat and temperature changes much more readily than ordinary brick.

Stone. Stone chimneys are necessarily large because of the thickness required of the walls. They can be built of any good grade of stone. If a flue lining is not used, the inside surfaces of the chimney should be finished as smooth as possible.

Concrete. Solid concrete masonry units[1] can be purchased with which it is possible to erect chimneys of practically any size and shape. These units have been sized so they are easily combined with the various sized rectangular and circular flue linings.

FLUE LININGS. Flue linings must withstand rapid fluctuations in temperature and at the same time be resistant to the action of ordinary flue gases. The shapes used should be of fire clay with shells not less than ⅝″ in thickness, and should be vitrified. Only sound flue linings should be used. Cracks and other imperfections in any part of the lining make the whole length unfit for use in a chimney.

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[1] For information, write the Portland Cement Association of Chicago, Ill., and ask for Circular No. CP66.

SEPARATE FLUES. Each device served by a chimney should have an entirely separate flue. This means there should be a flue for the furnace, another for the fireplace, and still another for the gas water heater. If more than one device is connected to the flue, the draft for each device is cut approximately in half. As an illustration of this, note Fig. 7. Here a stovepipe and furnace pipe enter the same flue. The draft for the furnace will be seriously cut down because the suction created by the rising fumes and gases will tend to draw a considerable amount of air through the stovepipe instead of through the furnace pipe. This reduces the efficiency of the furnace. The same explanation applies to flues for fireplaces. The only exception to the rule is where one flue might serve two small gas appliances such as water heaters without lowering efficiency. This rule is recommended to all masons engaged in the building of chimneys. Separate flues are

Fig. 7. Two Intake Openings in One Flue

worth while over and above the additional costs of chimneys.

Chimneys and Flues. It is good practice when designing and erecting chimneys to assume that soft coal will be used as fuel. If this is done, the flue size will be adequate to handle the results of the combustion of any fuel since soft coal produces the most smoke and soot and therefore requires the greatest flue area. All other fuels require less flue area so by planning on the use of soft coal, a comfortable margin of safety exists if it is not used. This practice makes certain that any type of fuel can be used.

Interior and Exterior Chimneys. Chimneys such as illustrated in Figs. 16 and 21 are called *interior chimneys* because they are built inside the structure they serve and are not exposed to the outside air except near their tops. Chimneys such as illustrated in Figs. 1 and 32 are known as *exterior chimneys* because they are built so all or the greater part of them are exposed to outside air.

The walls and flues of an interior chimney, being entirely within the buildings they serve, are always warm. This adds to the efficiency

of such chimneys because the ascending fumes and gases retain their heat and thus maintain a steady rise. On the other hand, because exterior chimneys have so much of their outer surfaces exposed to the outside air, cold weather reduces the temperature of chimney walls and flues which in turn reduces the temperature of the ascending fumes and gases. This cooling of the gases causes them to ascend less rapidly which in turn tends to reduce the draft. Thus, the exterior chimney is the less efficient of the two.

Exterior chimneys can be made more efficient by increasing the thickness of all walls which are exposed to the outside air. This will add greatly to chimney costs but is recommended nevertheless.

Chimney Resistance to Weather. The sections of interior chimneys which extend above roofs are subject to wind, rain, and frost. To protect these sections against the elements, proper precautions must be taken in their design and erection. Otherwise, chimneys in time will become unsafe. Most ordinary interior chimneys have walls which are 4″ in thickness. If flue linings are used, the 4″ thickness will be sufficient except for the part directly under and above the roof. Near the roof line, however, chimneys will tend to crack due to wind pressure during hard storms unless they are strengthened. This cracking occurs in the joints between the bricks. It makes chimneys structurally unsafe and they are likely to fall apart above the roof line. If flue linings have not been used, such cracking constitutes a dangerous fire hazard since sparks can easily pass through the opened joints and attack the woodwork of roofs. Rains and freezing temperatures also tend to loosen mortar joints as much as wind pressure.

In order to avoid these dangers, the wall thickness of interior chimneys is increased just under and above the roof line to at least 8″, as shown in Fig. 8. The thicker wall adds stability and overcomes any tendency for cracking resulting from wind pressures and rain combined with freezing temperatures.

All exterior chimneys such as shown in Fig. 1 should have walls at least 8″ thick. The design of such chimneys should be made by a structural engineer to insure their being safe from structural failures.

Exterior chimneys with less than four walls exposed to the outside air should have 8″ walls for each exposed area. Even if chimneys are parts of exterior building walls, their exposed sides should be 8″ walls.
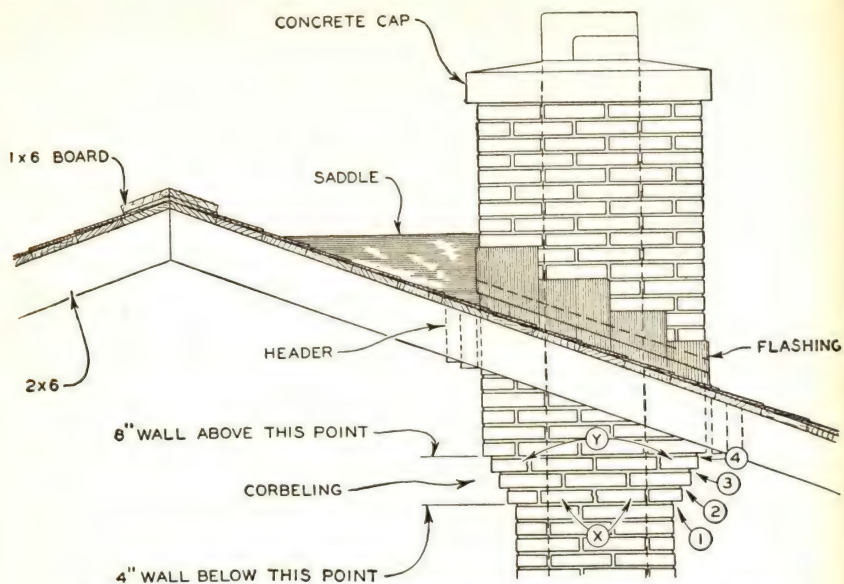
Fig. 8. Exposed Upper Section of Chimney Built with Eight-Inch Walls to
Resist Weathering
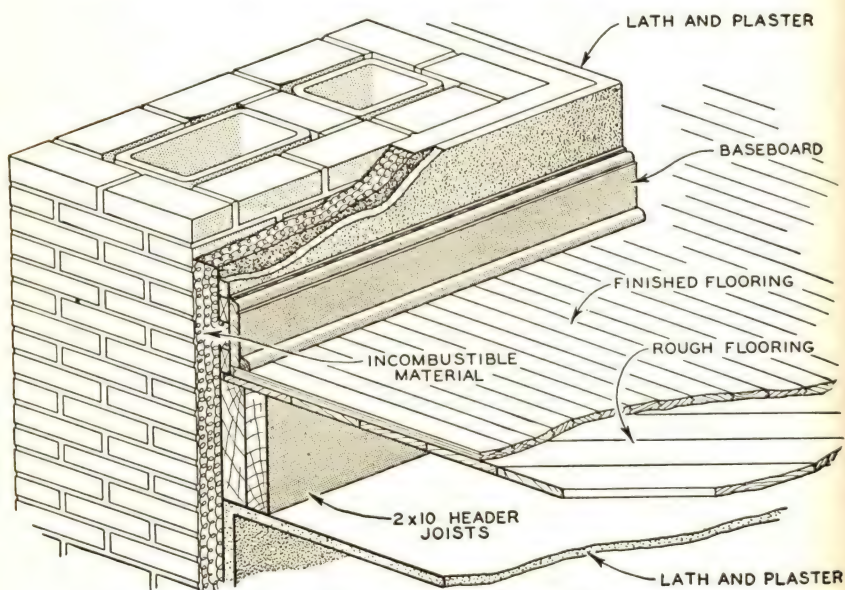
Fig. 9. Chimney Insulation Required in Wood Frame Houses

Insulation. All wood construction adjacent to chimneys should be insulated against fire. Even with flue linings, chimneys may develop one or more cracks due to unexpected settlement, severe winds, or other causes. The greatest care in erection will not completely eliminate this hazard. Therefore, a space of at least 2″ should be left between the outside faces of chimneys and all wooden beams and joists. This space should be filled with a porous, nonmetallic, incombustible material as shown in Fig. 9. The filling should be done before the floor is laid as it not only forms a fire stop but also prevents accumulation of shavings and other combustible material. Baseboards fastened to plaster which is in direct contact with the outside wall of the chimney should be protected by placing a layer of fireproof material at least 2″ in thickness between the chimney wall and the plaster, as shown in Fig. 9. Under no circumstances should wood studding, furring, or lathing be placed against a chimney. It is recommended that a coat of cement plaster be applied directly upon the masonry of chimneys which are to be encased by a wood partition or other combustible construction.

Chimney Connections. The connections between smoke pipes and chimneys should be carefully built to assure proper functioning and safety from fire. All openings for chimneys should consist of metal thimbles, around which the chimney brickwork should be carefully laid and cemented. Examples of the thimble and its use are shown in Fig. 10. The smoke pipes should fit tightly in the thimbles. If necessary, boiler clay or putty can be used to make the connections between the smoke pipes and thimbles airtight.

If furring is used on the thimble sides of brick chimneys, the thimbles should be installed by extending the bricks out around the thimbles. This construction is shown in (A) of Fig. 10. Where no furring is to be used, the thimbles are installed as shown at (B) in Fig. 10. Care should be taken to see that the thimbles are installed horizontally.

Note that in (B), of Fig. 10, the smoke pipe extends too far into the flue. The correct installation is shown at (A).

Soot Pockets. Soot pockets, which are shown in (A) and (B) of Fig. 10, should be provided for each range flue. Their use prevents soot accumulations from entering smoke pipes. These pockets need not be more than 8″ to 10″ below the smoke pipes. Such shallow pockets can

easily be cleaned out once a year by removing the smoke pipes. If the soot pocket is made much deeper, it will be impossible to remove all of the soot at the cleaning time and the pocket then becomes a fire hazard.
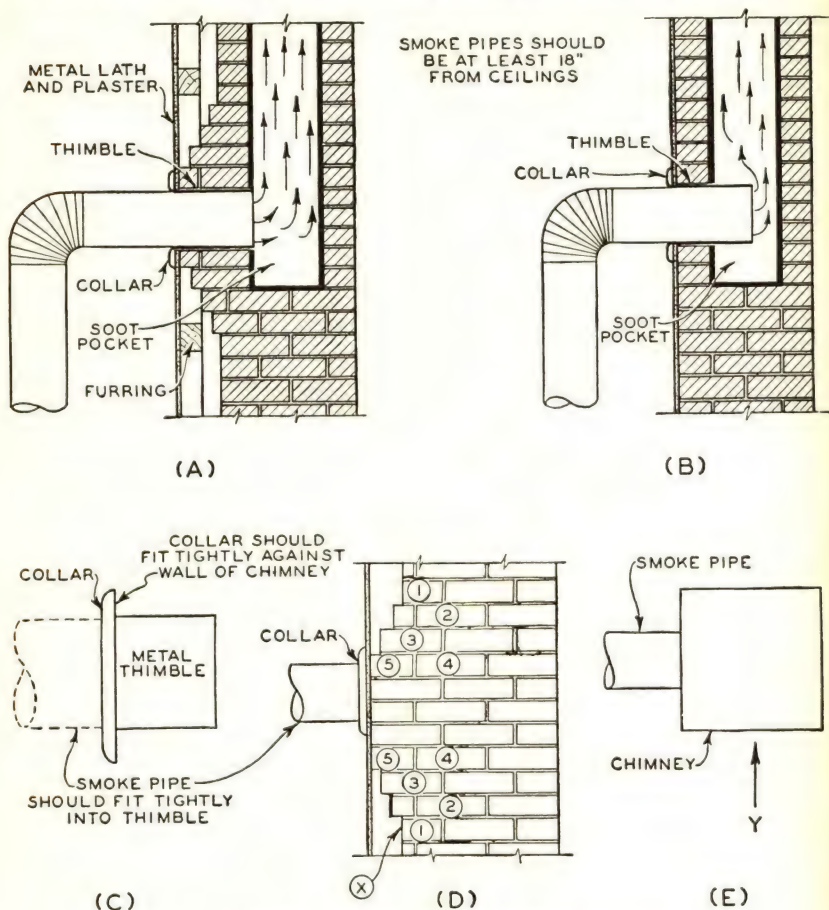
Fig. 10. Typical Smoke Pipe and Chimney Connections

It is advisable to extend the pockets for furnace flues to a point near the base of the chimney where cleanout doors should be provided as shown in Fig. 4. Such doors should be of metal construction. They should fit snugly and be kept tightly closed so that they do not admit any air to the flues. Such soot pockets should be lined the same as the other parts of the flue.

Flashing. Sheet metal flashings around chimneys where they pass through roofs have three general purposes. First, they provide a 2″ clearing around chimneys to allow for expansion due to temperature changes, settlement, or the slight movement of chimneys during severe winds. Second, they provide protection against fire. Finally, they help to make the junctions between roofs and chimneys watertight. Obviously enough, flashing is an important aspect of chimney construction.
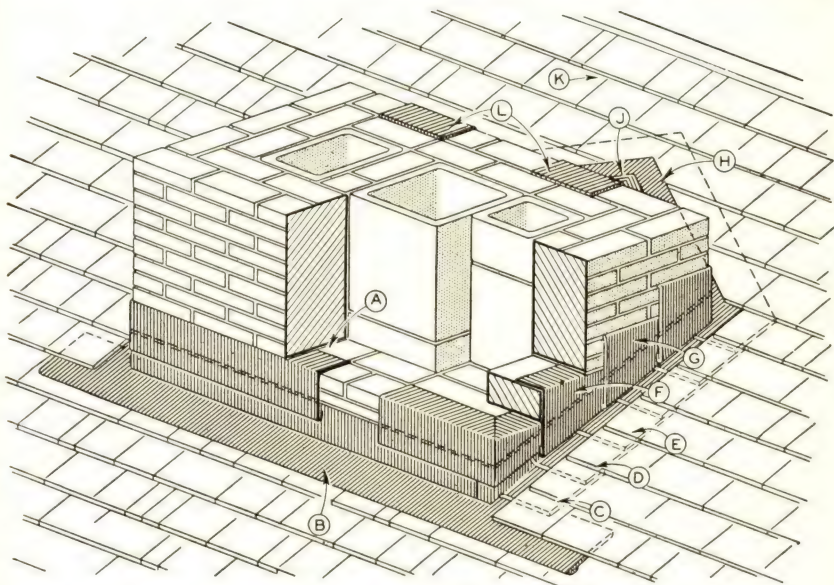
Fig. 11. Method of Flashing Chimney

Figs. 11 and 12 show flashing around a typical three-flue chimney. Since this chimney extends through a sloping roof, a *cricket* (sometimes called a saddle) is necessary. This is shown in detail in Fig. 12 and can be seen also in Figs. 8 and 11. The cricket is a means of shedding water around a chimney. Note how the counterflashing is built into the joints between the bricks at F and L in Fig. 11 and in Fig. 12. Note also that the sheet metal H over the cricket extends under the shingles K for at least 4″ and is counterflashed as shown in L of Fig. 12. Base flashing B, C, D, and E is lapped by cap flashing A, F, and G in Fig. 11, providing watertight construction. A full bed of mortar should be provided where cap flashing is inserted between bricks.

Corrosion-resistant metal such as copper, zinc, galvanized iron, or lead is the best material to use for flashings. If tin-coated steel is used for flashing, it should be well painted on both sides.

Spark Arresters. Spark arresters are more or less desirable where chimneys are near forests, lumber piles, or combustible roofs, depending on the kind of fuel, waste materials, or refuse that may be burned
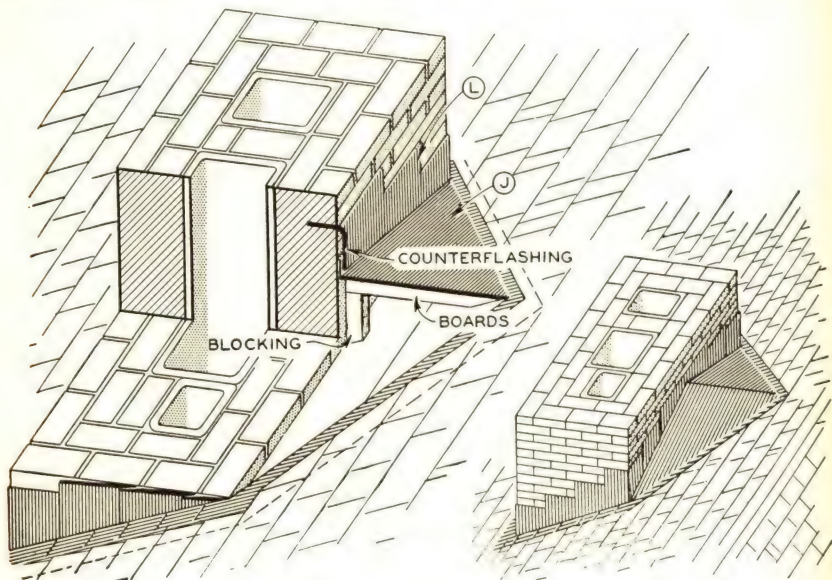
Fig. 12. Details of the Cricket Shown in Fig. 11

and the amount of deposits that may accumulate in the flues. While spark arresters cannot be depended on entirely to eliminate the discharge of sparks under all conditions, yet, when properly built and installed, they materially reduce the hazards from flying sparks, and are worth many times their cost of installation.

In general, all parts whether of wire, expanded metal, or perforated sheets, give longer service if they are rust-resistant material. Arresters for residences should have vertical sides extending upward not less than 9″ to provide a gross surface area at least twice that of the flue cross-section area. They should be kept outside the flue area and be securely anchored to the chimney tops. Openings in the screen not less than ⅝″ nor smaller than ⁵⁄₁₆″ in diameter are advisable.

Chimney Finish above Roofs. While common bricks are perfectly satisfactory for all hidden sections of interior chimneys, the use of face brick is advised for all exposed sections, as, for example, that above the roof. Face brick is much harder than common brick and resists weather better. Furthermore, it makes a much better appearance. Chimneys built of solid concrete units can be topped with face brick as a means of adding to the appearance of an otherwise drab, uninteresting structure.

Chimney Caps. To avoid frequent repairs, it is advisable to finish off the tops of chimneys with a durable material such as stone or concrete. The tops of chimneys are especially susceptible to weathering caused by rain, wind, freezing, and sharply changing temperatures.

Fig. 13 shows a simple but typical cap for one-flue chimneys. Note that the concrete portion of the cap should project beyond the chimney walls to prevent rain water from entering the joint between the cap and the chimney walls. This projection also adds to the appearance of the completed chimney. Also note that the flue lining should extend

ELEVATION

PLAN

Fig. 13. Concrete Cap Used on Single-Flue Chimneys

above the top of the concrete portion of the cap from 2 to 4 inches. The flue lining is surrounded with cement mortar to a depth next to the flue lining of about 2 inches. This mortar should be sloped from the sides of the flue to the edges of the concrete as shown by the plan and elevation views. This slope is required to direct air currents upward at the top of the flue linings and also, to drain water away from the flues. Fig. 8 shows a typical chimney cap for a three-flue chimney.

Chimney Hoods. Hoods are sometimes built as parts of chimneys as a means of making them more ornamental and to prevent rain water from entering the flues. A circular hood is shown in (A) of Fig. 14. If two or more flues exist in a hooded chimney, a *wythe* or *withe*, shown in (B), should separate them. Flat hoods, also shown at (B) in Fig. 14, are sometimes preferable, especially for large chimneys. In such types of hoods the flat top can be a slab of stone or concrete.

Hoods can be designed and built in many other ways depending on the taste of the designer.
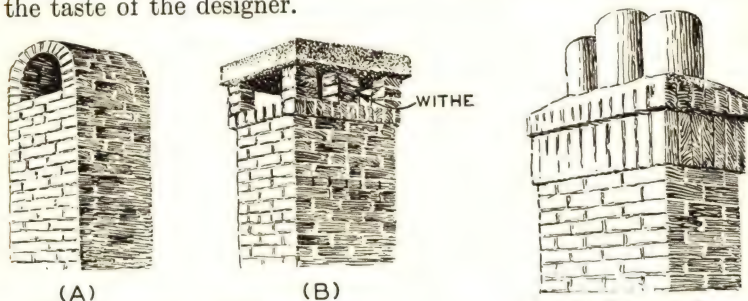
Fig. 14. Common Types of Chimney Hoods
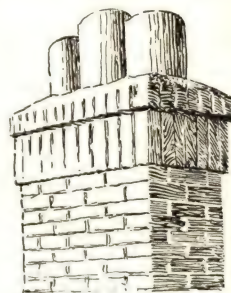
Fig. 15. Typical Chimney Pots

Chimney Pots. Fig. 15 shows typical chimney pots for a three-flue chimney. Such pots can be purchased ready to install and serve the purpose of caps. They add materially to the good appearance of a chimney, especially for large and ornamental types of residences. The pots must be of the same inside diameter as the flues of which they are a part.

KINDS OF CHIMNEYS

Single-Flue Interior Chimneys. Many residences and most stores and apartment buildings require chimney service only from central heating plants. Also, many farm homes and summer cottages require but one chimney for cook stoves or ranges. In such cases, one-flue chimneys serve the purpose satisfactorily.

Fig. 16 shows a small residence requiring only a one-flue chimney. This chimney can be seen in the plan and elevation views and also in the section of the chimney at the right of the illustration. This chimney can be classed as an interior chimney because it is entirely within the walls of the residence except, of course, the portion above the roof. Note that the chimney is supported by a concrete footing, that its walls are 4″ thick, that a flue lining is used, that a cleanout door is provided,
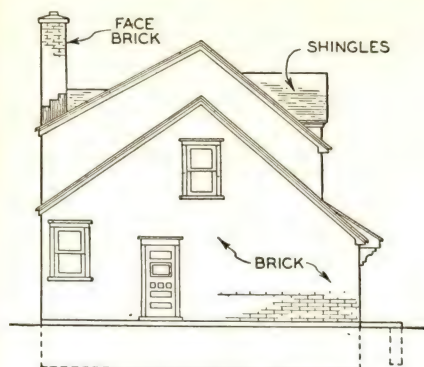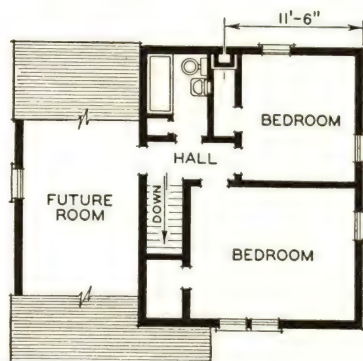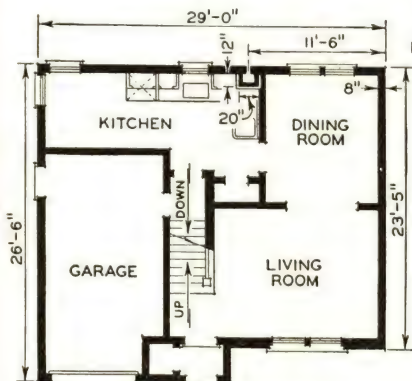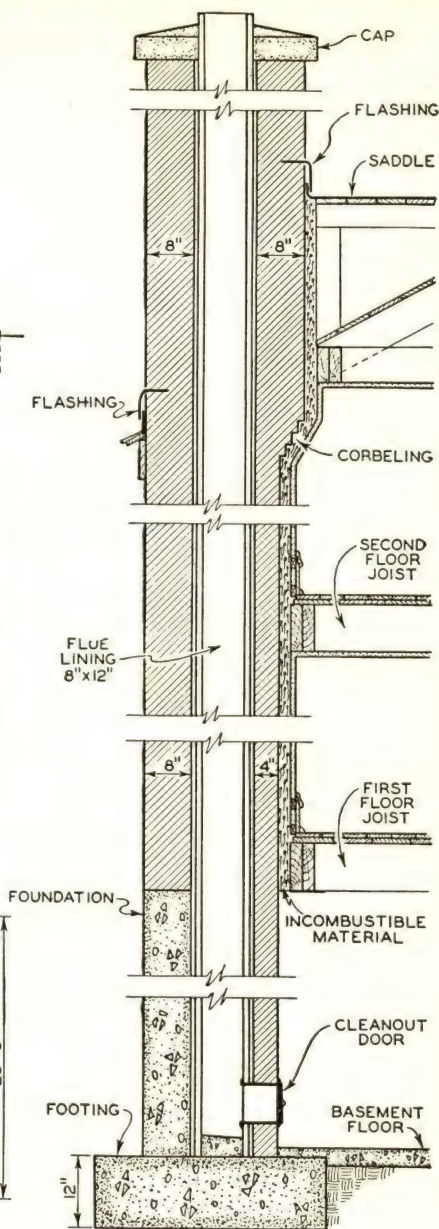
Fig. 16. Single-Flue Chimney and Its Location in a Small Residence
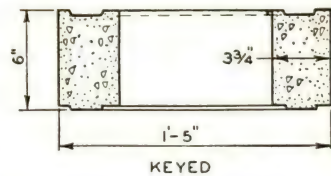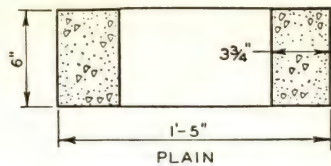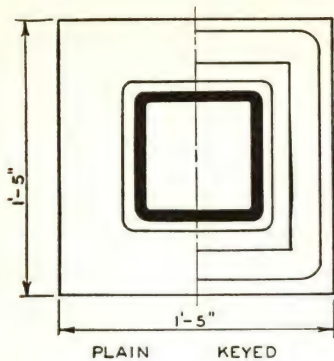
SOLID CHIMNEY UNIT FOR 8½" X 8½" CLAY FLUE LINER
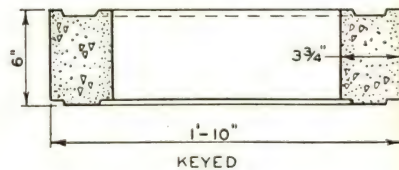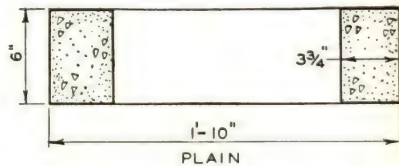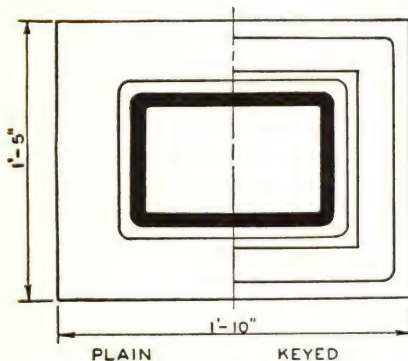
SOLID CHIMNEY UNIT FOR 8½" X 13" CLAY FLUE LINER
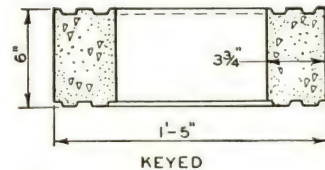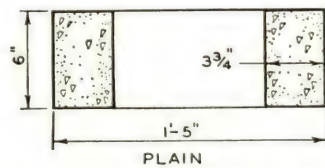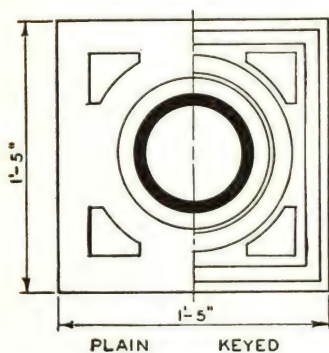
SOLID CHIMNEY UNIT FOR 8" ROUND, CLAY FLUE LINER

Fig. 17. Precast Concrete Chimney Units for Use with Clay Flue Liners of Various Sizes

that the top portion has walls of double thickness, and that a cap is employed. This chimney is well designed and, where only one flue is required, is a type to be recommended. If such a chimney is well built, it can be expected to function properly for the life of the residence with only minimum care needed throughout the years.

MATERIALS FOR ONE-FLUE INTERIOR CHIMNEYS. Probably the most common material used for building chimneys is brick masonry. Brick
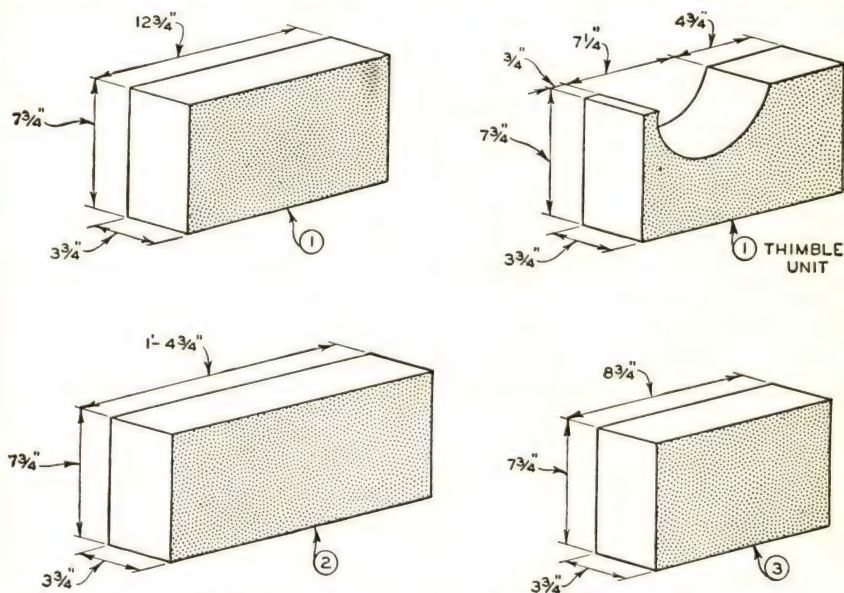
Fig. 18. Standard Size Solid Concrete Chimney Units for Use with Clay Flue Liners

masonry is popular for several reasons. Bricks are easily obtained in practically all parts of the country. Brick sizes are well adapted to work perfectly with standard flue linings. Brick structures are strong and reliable. Finally, bricks can be obtained in a variety of rich shadings which contribute to the natural beauty of buildings in which they are used.

Chimney brickwork should be laid with cement and lime mortar as such mortar is more resistant to the action of heat and flue gases. A good mortar to use in setting flue linings and all chimney masonry except firebrick consists of one part Portland cement, one part hydrated lime, and six parts clean sand, measured by volume. Slaked-lime putty

Fig. 19. Small Chimney Constructed Using Concrete Masonry Units Illustrated in Fig. 18
Courtesy of Portland Cement Association

may be used in place of hydrated lime. Firebrick is at its best when laid in fire clay.

The section view in Fig. 16 and Figs. 5, 7, and 10 all show typical, one-flue brick masonry chimneys.

Solid concrete masonry chimney units are also used to a great extent in building chimneys which can be perfectly vertical without slopes or other slight changes in direction. Fig. 17 shows the details of typical units used in the construction of three common single-flue chimneys. Note that the units can be obtained plain or keyed. The keyed units are recommended because they form a more solid, stronger, and more leakproof chimney. These units are sized so as to be usable with standard flue linings.

Fig. 18 illustrates other types of concrete masonry chimney units which can be used to construct single-flue or multiple-flue chimneys. Note that only three different sizes are shown. Yet with these three sizes, chimneys enclosing any combination of flue liners can be built. Fig. 19 shows a typical one-flue chimney constructed of such units as shown in Fig. 18.

Mortar for use in laying up concrete units should be the same as that used for brick masonry.

Two-Flue Interior Chimneys. In many instances residences have a fireplace in addition to a furnace. In such cases two flues are required. In situations as found in farmhouses where both a furnace and range are required, again, two flues are needed.

Figs. 20 and 21 show the basement, first and second floor plans, and an elevation view of a typical farm residence which has a furnace located in the basement and a range in the kitchen on the first floor. In the basement plan only one flue is shown in the chimney symbol. Only one flue is shown in the chimney symbol on the first floor plan even though the kitchen range is on the first floor. The reason for this is that the range flue begins between the first and second floors and does not extend down to the first floor level. Under such conditions this is common practice because of the saving in flue lining and labor. Both flues are shown in the plan of the second floor. Note that the overall chimney size is the same throughout.

Fig. 22 shows an elevation view of the chimney in Figs. 20 and 21. The vertical parallel lines composed of short dashes indicate the

FIRST FLOOR PLAN
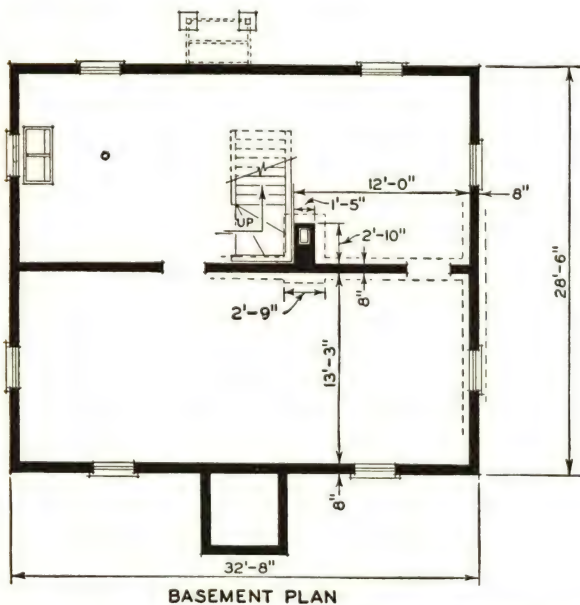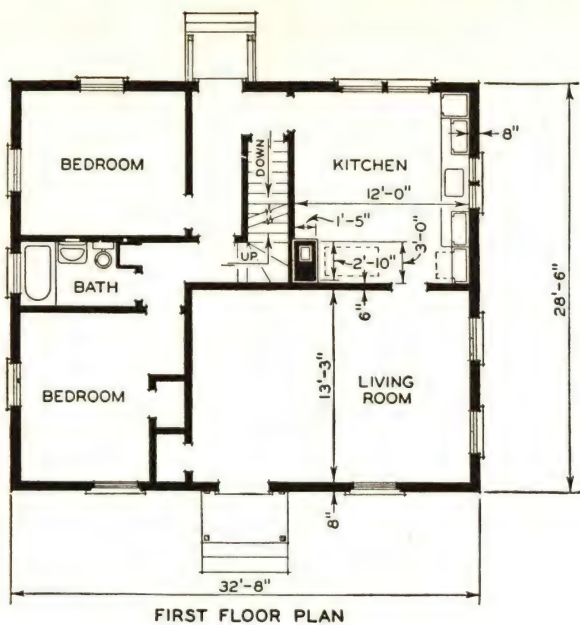
BASEMENT PLAN

Fig. 20. Basement and First Floor Plan of Farm Residence
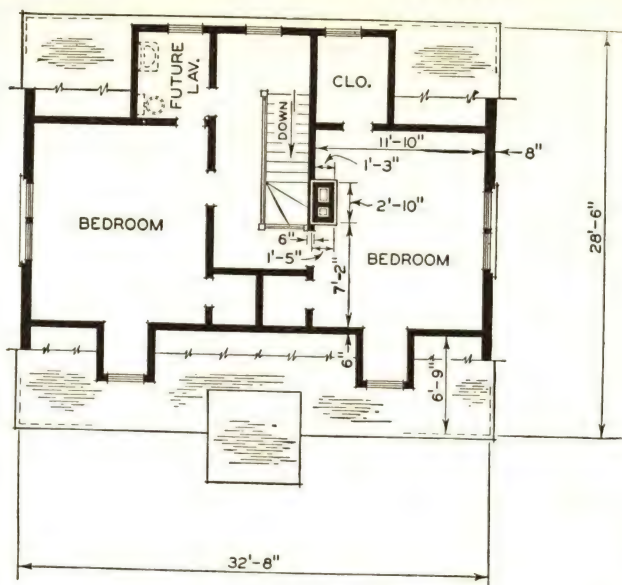
SECOND FLOOR PLAN
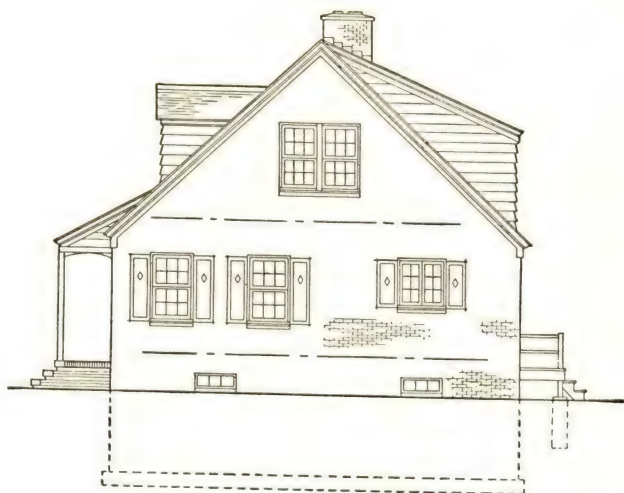
RIGHT SIDE ELEVATION

Fig. 21. Second Floor Plan and Right Side Elevation of Farm Residence
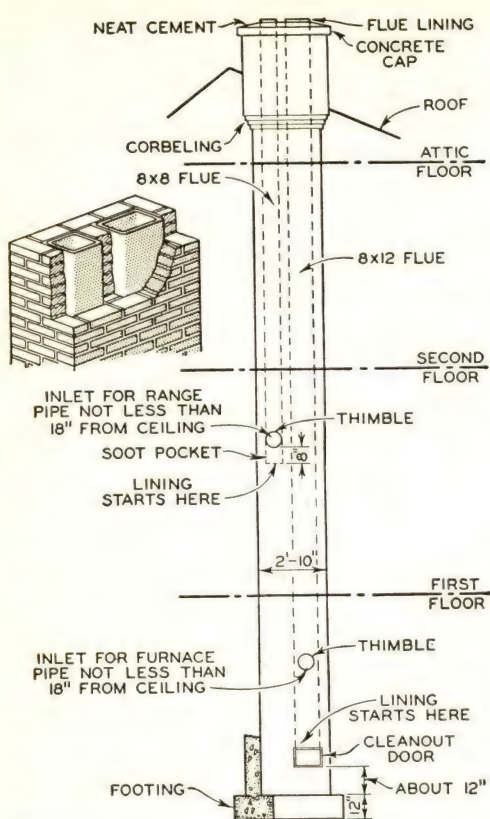
Fig. 22. Elevation View of Chimney in Figs. 20 and 21, Showing Flues

furnace and range flues. Note that a concrete footing is used and that the walls of the chimney are 4" thick. The walls are doubled in thickness above the roof, however, and flue linings are used. The furnace flue has a cleanout, the range flue has a soot pocket, thimbles are provided at both intakes, and the cap at the top of the chimney is an approved design. This is another well-designed chimney. If it is properly built it will serve the residence with but little care required.

MATERIALS FOR TWO-FLUE INTERIOR CHIMNEYS. Brick masonry is equally applicable to the two-flue chimney. The same mortar is recommended. Fig. 23 shows a section of the chimney illustrated in Fig. 22. The arrangement of the bricks and flue linings is typical.

Concrete masonry units which were shown in Figs. 18 and 19 can be used for two-flue chimneys as illustrated in Fig. 24. Note that either two 8½" x 13" flues or one 13" x 13" and one 4½" x 13" flue may be enclosed within the same combination of units. Many other flue sizes can be accommodated simply by changing the arrangement of the units.

Three-Flue Interior Chimneys. Residences occasionally have one or more small gas-burning appliances such as water heaters in addition to a fireplace and furnace. Figs. 3 and 4 illustrated this situation.

MATERIALS FOR THREE-FLUE INTERIOR CHIMNEYS. The materials

described and recommended for one- and two-flue chimneys are used for three-flue chimneys.

Single-Flue Exterior Chimneys. Single-flue chimneys, except those built for summer cottages, are seldom used for exterior chimneys because they are not large enough to have pleasing proportions. To build such a chimney larger merely for the purpose of ornamentation would be prohibitively expensive.

Two- and Three-Flue Exterior Chimneys. There are two general reasons why exterior chimneys of one kind or another having two or more
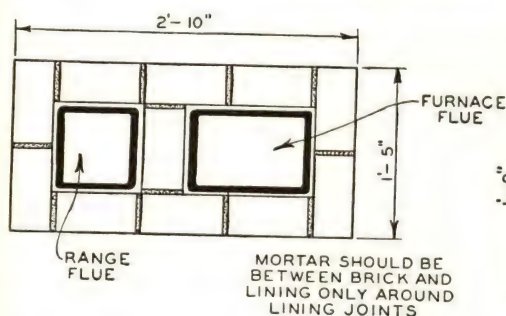
Fig. 23. Section above Range Intake of Two-Flue Interior Chimney Shown in Figs. 20, 21, and 22
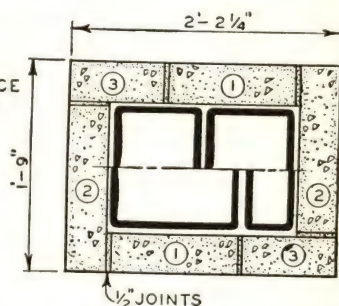
Fig. 24. Two-Flue Interior Chimney Constructed of Concrete Blocks of the Type Shown in Fig. 18

flues are employed for buildings such as residences. First, a chimney having more than two flues is of necessity large, and will take up a great deal of floor space. In addition to this, there is always the problem of where to place such a large chimney without seriously interfering with room arrangements. Second, where a large chimney is required, it can be used to good advantage as decoration or as part of the artistic design of the residence or other building it serves. Therefore, exterior walls become an excellent place for large chimneys with the main bulk of the chimney extending either into or out of the structure.

Fig. 25 shows an exterior chimney, the main bulk of which extends out of the residence. In this building there are two fireplaces on the first floor in addition to the basement furnace. This means that three flues will be necessary above the first floor level as shown in the small plan view taken at the second floor.

This chimney, extending out from the wall of the residence, does

SECOND FLOOR PLAN

ASH DUMP

FURNACE FLUE

FIRST FLOOR PLAN

FLUE CLEANOUT DOOR

FIREPLACE ASH DUMP
CLEANOUT DOOR   BASEMENT PLAN   FURNACE FLUE
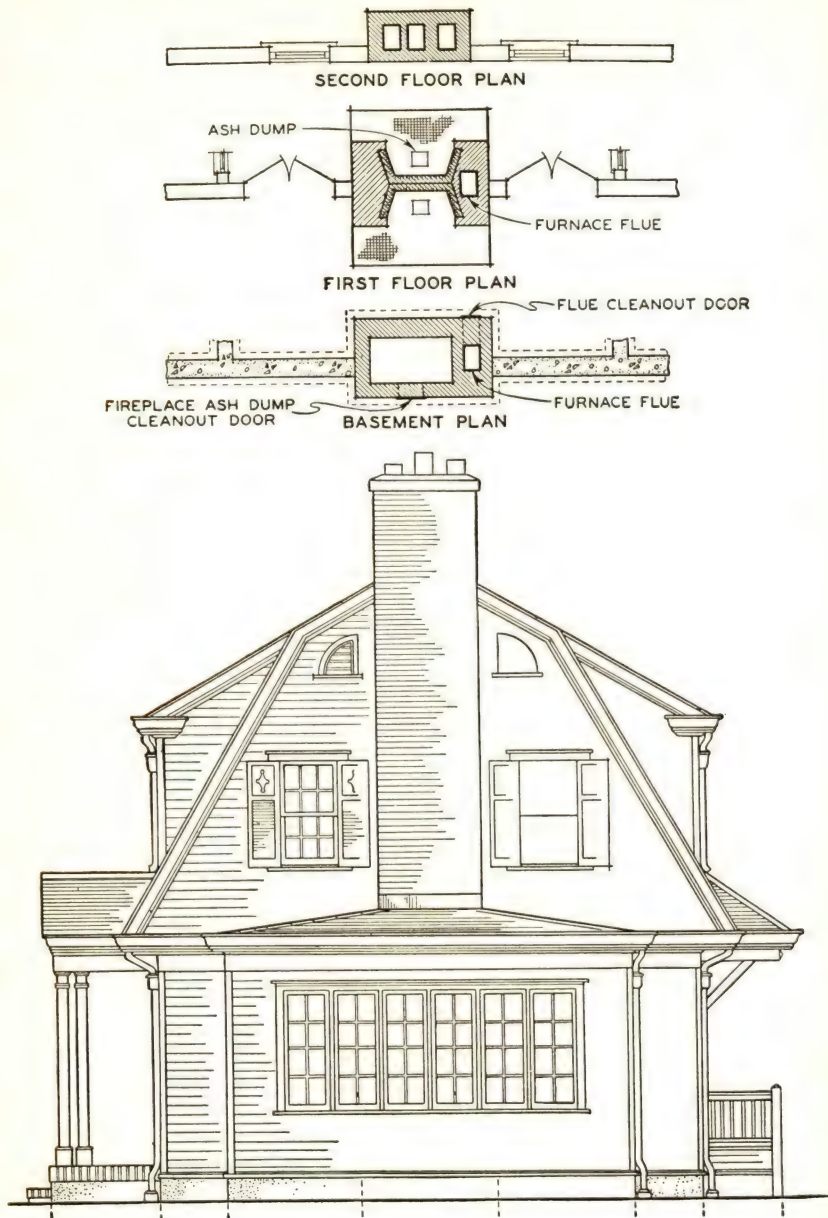
Fig. 25. Fireplace Chimney in Frame Wall with Projection on Outside of Residence
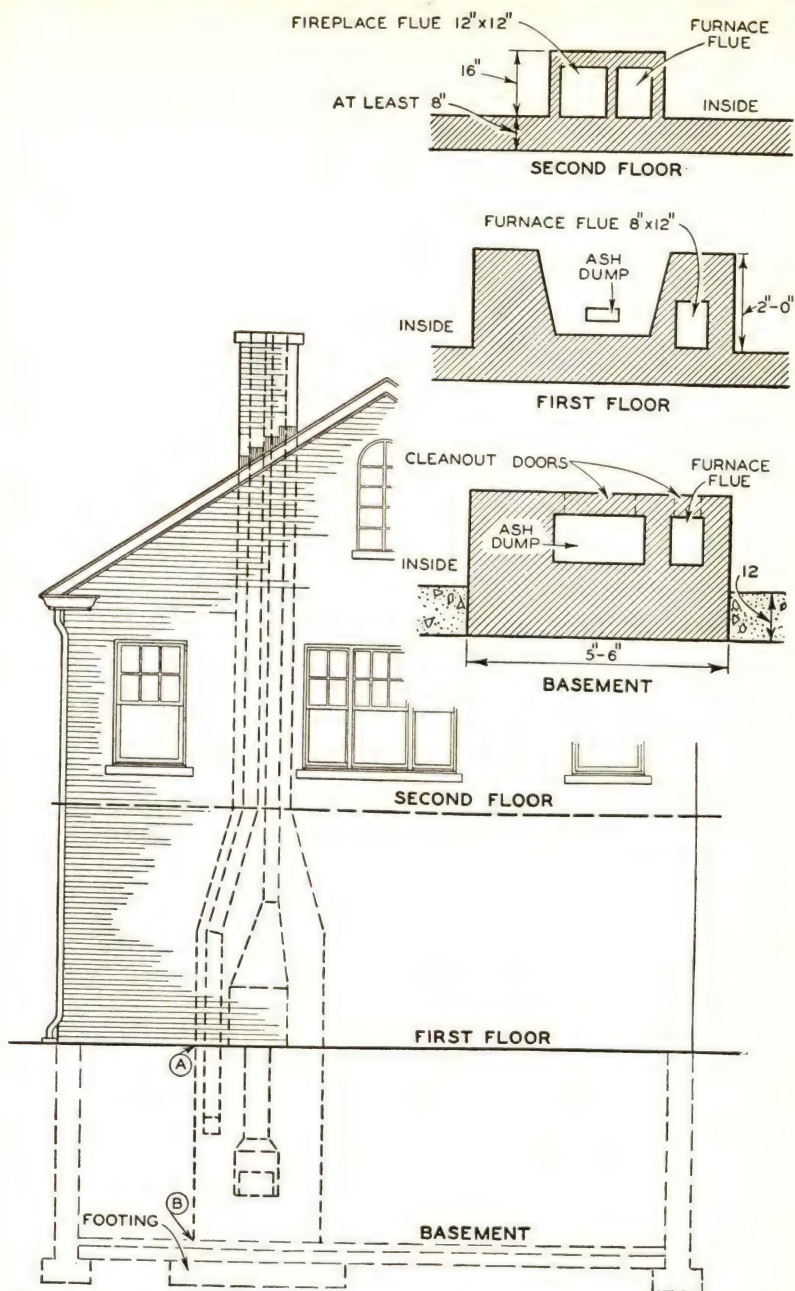
Fig. 26. Fireplace Chimney as Part of Wall with Projection on Inside of Residence

not take up valuable floor space on the second floor. It adds materially to the appearance of the residence by providing a center of interest and ornamentation.

Fig. 26 illustrates a two-flue chimney, the main bulk of which extends into the residence and which is part of one of the walls of the residence. This chimney serves a furnace and a fireplace. In this case the architect did not want the chimney to show because of the particular style of the residence. The idea was important enough to sacrifice interior floor space. Notice in both Fig. 25 and Fig. 26 that all walls of the chimneys which are exposed to the outside air are at least 8″ thick. This is the minimum recommended for satisfactory performance.

(A)   (B)

Fig. 27. Examples of the Use of Exterior Chimneys to Create a Decorative Effect

The stand-alone exterior chimney shown in Fig. 1 is an instance where the chimney, in addition to serving the fireplace, furnace, and gas appliances, forms the principal center of interest in the design of the residence. This kind of chimney is expensive to build because of the double thickness of the walls. In addition, it requires a certain amount of maintenance because it requires repointing from time to time.

MATERIALS FOR TWO- AND THREE-FLUE EXTERIOR CHIMNEYS. A variety of masonry materials, either alone or in combination, can be used for an exterior chimney, the main bulk of which extends out of the residence.

Brick. Brick is probably the most popular material used for all kinds of chimneys. Some very beautiful chimneys can be designed and built using this type of masonry. In addition to Figs. 1, 8, and 25 where brick exterior chimneys are shown, Fig. 27 illustrates how large ex-

terior chimneys can be used to great advantage to add to the appearance of residences. Neither of the residences in Fig. 27 would have an interesting appearance without the chimneys.

Stone. Stone can be used to great advantage in the construction of chimneys for any of several styles of residences. Fig. 28 shows two typical stone chimneys. Note that stone is also used for walls or parts of walls for the residences. In such cases stone chimneys add a great

(A)   (B)
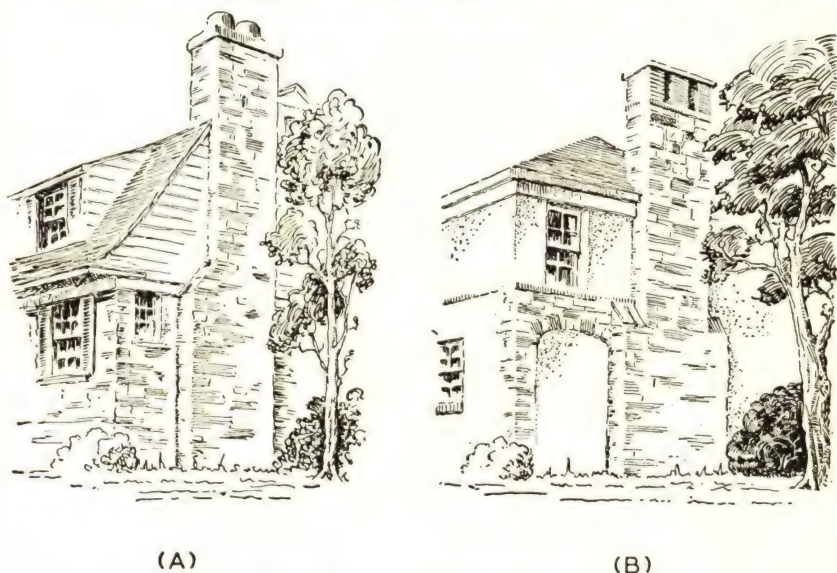
Fig. 28. Exterior Chimneys Built of Stone

deal to the appearance of the residences. It is not advisable to construct chimneys of stone unless stone is used to some extent in the residence walls.

Concrete. Solid concrete chimney units are not employed for exterior residence chimneys unless the walls of the residence they serve are of some sort of concrete ashlar. However, utility chimneys for store or industrial buildings are frequently built of such units since their purpose is functional only and there is no need for decoration.

Stucco. When stucco-surfaced exterior chimneys such as shown in Fig. 29 are desired, brick, concrete units, or hollow tile can be used for the chimney walls.

A pleasing appearance can be obtained for large exterior chimneys

Fig. 29. Exterior Chimney Having a Stucco Surface

Fig. 30. Combination Stone and Brick Exterior Chimney

Fig. 31. Chimney for Cape Cod Style of Architecture

through a combination of brick and stone as illustrated in Figs. 1 and 30. Best results are obtained in such a combination of materials by using the stone sparingly and near the bottom of such chimneys.

Style Chimneys. As a general rule residences are designed in imitation of the so-called traditional styles of architecture. Chimneys for
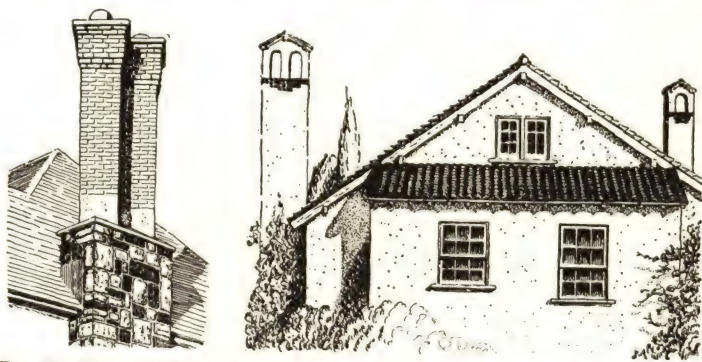
Fig. 32. Chimney Types for Tudor and Mediterranean Styles of Architecture

such houses must follow the same general style characteristics. For example, the residence shown in Fig. 31 is Cape Cod in style and, following the dictates of that style, the chimney is large. Fig. 32 illustrates chimney design following Tudor and Mediterranean architectural styles. The chimney shown in (A) of Fig. 28 corresponds with the Dutch Colonial style of the residence, while the chimney in Fig. 29

follows the Spanish style. In like manner, the chimney shown in (A) of Fig. 27 follows the Elizabethan or English half-timbered style, the chimney in (B) of Fig. 28 follows the modified Mediterranean style, and the chimney in (B) of Fig. 27 follows the Cape Cod style. From this it can be seen that the designer of chimneys which are to be parts of definitely styled houses should put as much character into the chimneys as in the general design of the house.
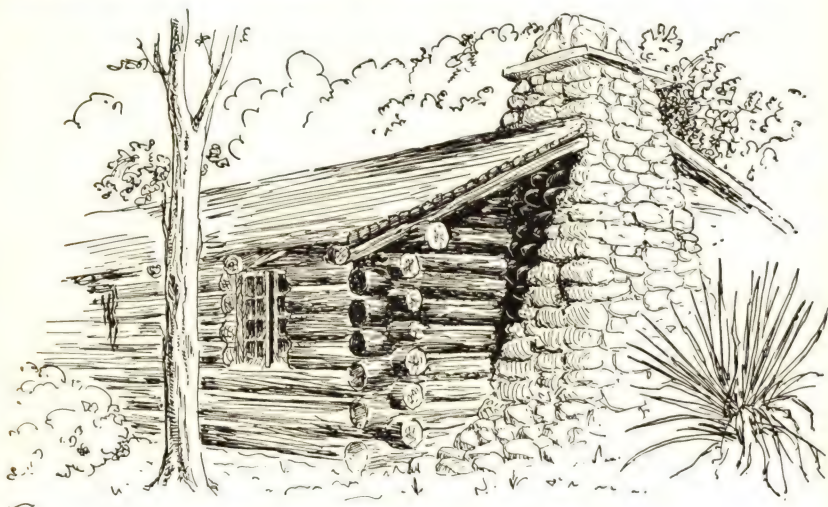
Fig. 33. Stone Chimney for Log Cabin Summer Cottage

COTTAGE CHIMNEYS. In summer cottages where fireplaces are one of the main points of interest, stone chimneys, especially for log cottages, harmonize with rustic surroundings. Fig. 33 shows such a typical pleasing fireplace chimney. This chimney is too short to provide a good draft for a stove or range but will serve a fireplace satisfactorily.

Chimneys with Offsets. Sometimes it is necessary to change the vertical direction of the chimney slightly because of one or more architectural considerations. This change of direction is called an *offset*. Fig. 34 shows an unlined offset in (A) and one that is lined in (B). In the interests of structural safety, the amount of offset must be limited so that center line XY of the upper flue will not fall beyond the center of the wall of the lower flue. Note that when offsetting an unlined chimney, the offsetting begins and ends two courses earlier in the wall

toward which the flue is offset. In (A) of Fig. 34, it is the left wall which begins its offset first. The reason for this is to maintain the same area throughout the flue offset after plastering.

Chimneys below Grade. It is not uncommon for part of a chimney such as the one shown in Fig. 26 to be made of concrete instead of brick or stone. For example, in Fig. 26, the section of chimney marked *AB*
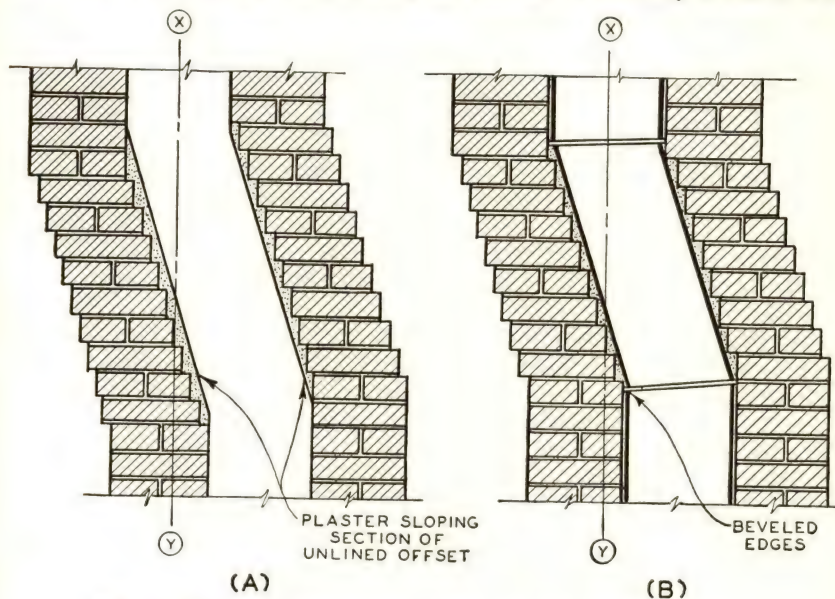
Fig. 34. Chimney Offsets without Lining, (A), and with Lining, (B)

could be concrete and an integral part of the foundation. The openings for the flues and ash dumps are provided by wood forms at the time of pouring.

DESIGN OF CHIMNEYS

Foundations. Every chimney must have a foundation of sufficient size to provide ample support. This support is necessary to prevent settlement and other obvious difficulties. Except for an explanation of the method used in determining the weight of a chimney, the building of chimney footings was fully discussed in Chapter II.

The finding of the approximate total weight of a chimney is simply a matter of determining the total cubage of the masonry and multi-

plying that figure by the weight of the masonry per cubic foot. For general purposes all cubage calculations can be estimates more or less so long as the possible error is on the safe side or greater than it actually is.

As a means of illustrating the method of finding the weight of a particular chimney, it will be assumed that the weight must be found of the chimney shown in section in Fig. 23. The height of this chimney is given as 30′ 0 inches.

The cross-section dimensions are 2′ 10″ x 1′ 5 inches. For ease in calculating, these dimensions will be called 3′ 0″ x 1′ 6 inches. Note that the dimensions were *increased* to the nearest convenient dimension. This puts the calculation on the safe side. The area of the section is then 3 × 1½ feet, or 4½ feet. The large flue has an inside dimension of 8″ x 12″ and the small one 8½″ x 8½″, or 96 and 72.25 square inches respectively. This makes a total of 168 square inches. One square foot contains 144 square inches. Again, for ease in calculation and to be on the safe side, assume the area of both flues to be one square foot Then, 4½−1=3½ square feet which is the area of the masonry work in the section of chimney under consideration. Multiplying 3½ by 30 equals 105 cubic feet, which is the total cubage of the entire chimney including the flue lining. If brick masonry, including the flue lining, is assumed to weigh 130 pounds per cubic foot, the total weight of the chimney is 105 × 130, or approximately 14,000 pounds.

If the chimney is to be made of solid concrete units, the same procedure is followed except that the masonry is assumed to have a weight of 150 pounds per cubic foot. Stone chimneys can be assumed also to weigh 150 pounds per cubic foot.

This method of calculating the weight of a chimney is used only where the chimney has the same over-all dimension from top to bottom. For fireplace chimneys and where chimneys are enlarged at the top, such as the chimney in the sketch in Fig. 35, the weight of each different section must be calculated separately.

For example, the portion of chimney top between points *AB* in Fig. 35 is treated in the same manner as described for the chimney shown in Fig. 23. The area, cubage, and weight are found, assuming the height dimension starts where the corbeling begins and extends to include the concrete cap. Chimney portion *BC* is handled in the same

way described for Fig. 23. Portions CD and DE are assumed to have the same flue areas as sections AB and BC. The areas of the fireplace and ashpit are disregarded. The total of all the section weights is the weight of the chimney.

Unlined and Lined Flue Sizes. Before a chimney can be designed or redesigned, the type of heating plant, grate area, and kind of fuel to be burned must be known. This information is necessary because the dimensions of the flues depend principally upon these three points.

Manufacturers of heating equipment occasionally supply, or will supply upon request, information concerning flue sizes and chimney heights which they know is necessary in order that their equipment will function to the best advantage. When such specifications are not available, the chimney design is made on the basis of what is known concerning the heating plant to be used, grate size, and fuel.

In many sections of the country in recent years there has been a tendency to

Fig. 35. Elevation for Fireplace Chimney in a Residence

design flues which are suitable only for use with piped fuels. While this may seem economical since a smaller flue will serve such fuels satisfactorily, it could result eventually in unwarranted expenditures. If for one reason or other the supply of piped fuels became unavailable and a change to coal was necessary, the small flues would not be adequate and it would be necessary to rebuild the chimneys. To prevent such needless expense, chimneys should be designed to fit the needs of soft coal. Such chimneys will meet the needs of any fuel.

In this chapter the use of flue lining has been assumed as standard practice. However, the explanations given apply equally well to unlined flues.

TABLE I. DIMENSIONS OF COMMONLY USED STANDARD COMMERCIAL
FLUE LINING

RECTANGULAR LININGS*				ROUND LININGS†			
Outside Dimensions (Inches)	Cross-sectional Area		Wall Thickness (Inches)	Inside Diameter (Inches)	Cross-sectional Area		Wall Thickness (Inches)
	Inside (Sq. In.)	Outside (Sq. Ft.)			Inside (Sq. Ft.)	Outside (Sq. Ft.)	
4½ x 8½.....	23.6	0.26	⅝	6.........	28.3	0.29	⅝
4½ x 13......	38.2	.41	⅝	8.........	50.3	.49	¾
7½ x 7½.....	39.1	.39	⅝	10.........	78.5	.75	⅞
8½ x 8½.....	52.6	.50	⅝	12.........	113.0	1.07	1
8½ x 13......	80.5	.78	¾	15.........	176.7	1.62	1⅛
8½ x 18......	109.7	1.10	⅞	18.........	254.4	2.29	1¼
13 x 13......	126.6	1.20	⅞	20.........	314.1	2.82	1⅜
13 x 18......	182.8	1.70	⅞	22.........	380.1	3.48	1⅝
18 x 18......	248.1	2.30	1⅛	24.........	452.3	4.05	1⅝
20 x 20......	297.6	2.60	1⅜	27.........	572.5	5.20	2

*All rectangular flue lining is 2′0″ long.
†Round flue lining, 6″ to 24″ in diameter, is 2′ 0″ long; that 27″ to 36″ in diameter is 2′ 6″ or
3′ 0″ long.

Table I shows the dimensions of commonly used rectangular and
round standard commercial flue lining. The rectangular sizes less than
8½″ x 8½″ are frequently employed as vents for gas-fired water heat-
ers and other such appliances. The round sizes less than 8″ in diameter
are generally used for the same purpose. Manufacturers of such appli-
ances will supply information concerning required flue sizes.

Table II shows sizes of flue linings and chimney heights recom-
mended for flat-grate furnaces burning soft coal.

TABLE II. SIZES OF FLUE LININGS AND HEIGHTS OF CHIMNEYS RECOMMENDED
FOR FLAT-GRATE FURNACES BURNING SOFT COAL

Grate Area (Sq. Ft.)	NOMINAL SIZE OF FLUE LINING IN INCHES								HEIGHT IN FEET OF CHIMNEY TOP ABOVE GRATE AT ELEVATION INDICATED			
	Round (Inside Diameter) at Elevation Indicated				Rectangular (Outside Dimensions) at Elevation Indicated							
	Sea Level	2,000 Feet	4,000 Feet	6,000 Feet	Sea Level	2,000 Feet	4,000 Feet	6,000 Feet	Sea Level	2,000 Feet	4,000 Feet	6,000 Feet
1...	8	8	8	10	8½ x 8½	8½ x 8½	8½ x 8½	8½ x 13	22	26	32	36
2...	10	10	10	10	8½ x 13	8½ x 13	8½ x 13	8½ x 13	24	29	35	41
3...	10	10	12	12	8½ x 13	8½ x 13	13 x 13	13 x 13	26	33	41	49
4...	12	12	12	12	13 x 13	13 x 13	13 x 13	13 x 13	30	37	45	49
5...	12	12	15	15	13 x 13	13 x 13	13 x 13	18 x 18	32	37	43	52
6...	15	18	18	18	18 x 18	18 x 18	20 x 20	20 x 20	30	37	47	56
7...	18	18	18	18	20 x 20	20 x 20	20 x 20	20 x 20	32	41	49	64
8...	18	18	18	18	20 x 20	20 x 20	20 x 20	20 x 20	35	42	56	70

Note that Table II is based on various elevations. The term "eleva-
tion" means the distance above sea level. For example, Chicago, Illi-
nois, is about 600 feet above sea level whereas Denver, Colorado, is
exactly one mile high. The elevation of any particular locality can be
obtained from the offices of the county surveyors or recorders. Eleva-

tion is an important factor in offsetting loss in drafts, especially above 4,000 feet.

The following notes apply to Table II and to chimneys in general:

1. If anthracite (hard coal) is to be burned exclusively, the required flue area sizes may be reduced by about 25 per cent. However, this is not a recommended procedure as has been pointed out previously.

2. Table II is based on lined flues with no offsets greater than were explained in connection with Fig. 34. However, unlined flues may be included if the joints facing the flues are carefully finished so they are smooth.

3. The smallest sizes of fuels require excessive drafts. Chimneys for them should be made 10 per cent higher.

4. Good design practices advise against using one flue for more than one heating device such as stoves and furnaces. However, if a condition exists requiring that two such devices be served by the same flue, their total grate area may be reduced by 15 per cent. If two gas-fired appliances such as water heaters must be connected to one flue, then the flue should be increased in size at least from 6″ to 8″, or larger if possible.

Table II is also based on grate areas as indicated in the first column on the left-hand side of the table. The manufacturer of any stove, range, or furnace designed to burn coal either shows the recommended grate areas on his equipment or will furnish such information on request. Also, the installers of furnaces will know the grate areas because they must calculate the required grate area for each and every furnace or boiler they install.

Most laundry stoves and kitchen ranges can be served satisfactorily by 8½″ x 8½″ or 4½″ x 13″ rectangular and 8″ round flues.

The sectional area of fireplace flues should have a direct relation to the area of fireplace openings. The area of lined flues should be 12 per cent or more of that of the fireplace opening. If the flues are unlined, the proportion should be increased slightly because of the greater friction. Seventeen square inches of area for chimney flues to every square foot of fireplace opening is a good rule to follow. For example, if a fireplace opening has an area of 8.24 square feet, the sectional area of the required flue should be 140 square inches. It is seldom possible to obtain standard linings of the exact required sectional areas. However, care should be taken to always select linings which are too large rather than too small.

For practice in the determination of the proper size necessary for a particular flue, assume it is desired to know the flue size for a chimney having a grate area of 4½ square feet in which anthracite is to be

burned. The furnace is at an elevation of 3,500 feet and a rectangular flue is to be used.

Since the 3,500 elevation is well over 2,000 feet and since Table II is figured only for elevations in multiples of 2,000 feet up to 6,000, it will be assumed that the elevation is an even 4,000 feet. At 4,000 feet, a grate area of 5 square feet, according to Table II, requires a round flue having a diameter of 15 inches. However, when anthracite is used as fuel, it is permissible to reduce the flue size by 25 per cent, assuming that bituminous coal will never be used. The flue size needed will be 11″ in diameter since 25 per cent of 15 is 3.75, or 4, for ease in calculation. Since there is no standard 11″ flue, a 12″ lining will be used.

Suppose that one heating device having a grate area of 3 square feet and another having a grate area of 1½ square feet must be connected to a single flue in a locality 2,000 feet above sea level. What size rectangular or round flue should be used?

Adding the two grate areas gives an answer of 4½ square feet. This total area is reduced by 15 per cent. Thus, the original area of 4½ square feet becomes 3.8 square feet which is the required area. Since the grate sizes in Table II are given only in whole numbers, the nearest whole number, 4, is taken. From Table II it can be seen that for a grate with an area of 4 square feet at an elevation of 2,000 feet, either a 13″ x 13″ square flue or a 12″ diameter round flue will be necessary.

Height of Chimneys. The higher chimneys are built, the better is the draft they provide. High chimneys are less subject to counter air currents and actually produce stronger and more constant drafts.

Table II also gives the heights recommended for chimneys having various sized flues and located at several different elevations. These heights, while constituting the best possible design, cannot always be used, especially in one story residences and other small buildings. Therefore, any building being considered should have a chimney designed as near the recommended height as possible with due care being given to the following suggestions:

1. Chimneys should extend at least 3′ above flat roofs and 2′ above the highest ridge of peak roofs.
2. Where chimneys cannot be built high enough above ridges to prevent trouble from eddies caused by the wind being deflected from the roof, hoods such as shown in (A) of Fig. 14 may be provided with the open ends parallel to the ridges.

3. Eddies, which force air down the flues, may be caused by erecting chimneys too near adjoining higher buildings. To avoid such possibilities, chimneys should be planned on sides of buildings away from higher buildings or, if this is not possible, the chimneys should be built higher than the top level of the adjoining buildings.

Metal-pipe extensions for chimneys, while not attractive, can be used to increase the height of flues. Such extensions can be provided with metal cowls which turn with the wind and prevent the air from blowing down the flues.

Chimney Locations. As previously explained, the best location for chimneys is within buildings since protection against the cold is afforded and the chimney walls, therefore, will always remain warm. However, because of architectural and utility considerations, such practice is not always possible.

Locating the chimney also requires the consideration of the room arrangements within the building. The best time to plan chimney locations is when the building is being designed. At that time the various rooms and closets can be arranged in the most convenient pattern and the furnace and fireplace locations decided. However, the number and size of the flues must be known before the chimney can be designed or its location planned. The size of the flues can be found by carefully estimating the sizes of the furnace and fireplace and any other heating device.

Chimney Walls. The following material is a summary of the principles which govern the design and construction of chimney walls:

The walls of either interior or exterior chimneys having unlined flues should be 8" thick and the brick constituting the flue lining should be firebrick. The walls of interior chimneys having lined flues can be 4" thick. The walls of exterior chimneys, even with lined flues, should be 8" thick on all sides exposed to outside air. The above-the-roof walls of interior chimneys should be increased to a thickness of 8 inches.

The linings for each flue should be separated by a 4" wythe. Chimney walls around fireplaces should be at least 3" thick. Spaces between brick and flue linings, whether round or rectangular, should be solidly filled with mortar near the lining joints. Unlined flues should be plastered only at offsets.

The foregoing suggestions apply equally well to chimneys built of solid concrete units 4" thick. The walls of chimneys constructed of stone should be at least 12" thick under any conditions.

Solid Chimney Bottoms. Some authorities urge that the bottom portions of chimneys which do not contain fireplaces be composed of solid masonry as a means of giving the chimneys more stability and to distribute the load (weight) more evenly over the foundations. This principle, while making chimneys somewhat more expensive, has merit and could be followed to good advantage. If such a suggestion is followed, for example, in connection with the chimney shown in the section view of Fig. 16, the cleanout door could be planned at a point 4′ or 5′ above the footing and the chimney from that door to the foundation made solid.

BUILDING CHIMNEYS

Foundations. The first step in the building of chimneys is the pouring of the concrete footings (also called foundations with respect to chimneys). These footings are an absolute necessity. Before such footings can be poured, their size and location must be accurately determined.

When architects draw the working drawings for buildings such as shown in Figs. 16, 20, and 21, they calculate the correct size for chimneys, their locations, and the size and location of the chimney footings. All such information is shown in the working drawings (blueprints) by dimensions. For example, note in the basement plan of Fig. 20 that there are exact dimensions which specify the chimney size, the chimney location, and the exact size and location of its footing. From such working drawings or plans masons can quickly determine the necessary footing dimensions and locations. Once the size and position of chimney footings have been determined, they are laid out and poured as described in Chapter II. In most cases, chimney footings are poured as integral parts of foundation footings. Such is the case for the chimney footings shown in Figs. 20, 25, and 26.

Locating Chimneys. When the chimney footings are in place, the exact position of the chimney base is outlined on the surface of the footing with chalk, taking the dimensions from the working drawings.

Joint Thicknesses. Joints of ¼″ or ⅜″ are recommended for chimney brickwork. The ¼″ joints produce the strongest masonry work. In unlined flues, the joints facing the flues should be struck absolutely smooth and flush with the sides of the bricks so there are no small ledges or

other rough places to cause friction or gather soot. The exterior joints for chimneys hidden by structural parts of buildings can be smoothed and made flush with the sides of the brickwork by passing the trowel over them while pressing the trowel against the brickwork. For joints above the roof and for all other brickwork exposed to the weather, the joints should be carefully pointed.

Joints should not exceed ½" when chimneys are built of solid concrete units. Care should be taken to shove all vertical joints tight. All joints should be smooth and flush with the sides of the concrete units. The joints for stone chimney masonry may vary as explained in the chapter on Footings. However, all joints should be made smooth and the mortar should not extend between the faces of the various stones. Also, the mortar should be carefully troweled at the edges of each joint to be sure it is solidly against the stones in the joint. This is done by using a small pointing trowel or the point of the standard trowel.

Installing Flue Linings. Chimney flue linings should start at the soot pockets, cleanouts, or above fireplaces (see Figs. 3, 4, and 25) and extend continuously to the cap. The lowest unit of lining in every flue should be supported on at least three sides by brick, solid masonry units, or a stone course projecting from the inside wall of the chimney to the inside wall of the lining. This provides a sure support and prevents any possibility of the lining slipping downward where the joints cannot be repaired.

When the supports for linings are prepared, mortar should be applied at all points where the units of lining will rest. The units of lining should be pressed carefully down on this mortar to insure a firm bed. Care must be taken to see that the joint between the lining and the support is not more than ½ inch. The joints on the inside of the lining must be smoothed and made flush with the surface of the lining so that no small ledges or projections are left.

When the chimney walls have progressed to the top of each unit of lining, the next unit should be placed on the mortar bed on the top of the previous unit and pressed down as previously described. This process is continued to the top of the chimney. In laying up the walls and linings of a chimney, it is advisable to draw a tight-fitting bag of straw up each flue as the work progresses. This will catch any material which might fall into and block the flue.

When necessary, flue lining can be cut by first filling the section with damp sand which is tamped solid. A sharp chisel and light hammer are then used to make small cuts along the line where the cut is to be made. When enough of these small cuts have been made on all sides of the lining, it will finally break cleanly.

When linings are installed in chimney offsets such as shown in Fig. 34, the edges of the linings should be carefully beveled.

Installing Cleanout Doors. When the courses of masonry (brick, concrete units, or stone) are up to the level of the lower edge of the cleanout doors, the doors themselves can be set in place. These doors can be purchased with flanges on all four sides at most building materials yards. A bed of mortar is placed on the masonry and the bottom flanges of the doors pushed into it. The masonry is then placed around and over the other three sides of the doors, making certain that the mortar makes tight joints against all sides of the doors.

Installing Thimbles. When thimbles must be connected to flue linings, the holes in the linings can be cut by using a filling of damp sand as was described for the cutting off of lining units.

Thimbles can be purchased ready to install. The masonry work is built up to the points where the thimbles are to be located and the thimbles placed in position in a good bed of mortar. If brick or stone masonry is being used, individual units can be broken or chipped to fit around the thimbles as the courses are laid. The mortar joints around the thimbles should be tight. When solid concrete masonry units are used, regular thimble units such as those shown in Fig. 18 can be employed.

Corbeling. When corbeling is required because of a chimney offset such as shown in Fig. 34, each succeeding brick or course should extend out not more than an inch beyond the course below. The same rule applies to solid concrete units and stone.

When corbeling is required to increase the thickness of chimney walls as shown in Fig. 8, the succeeding courses such as *1, 2, 3,* and *4* should extend out not more than two inches beyond the courses below. Note in Fig. 8 that bricks *X* and *Y* have been shortened by cutting. The irregularity of brick lengths in two of the courses is not serious because that portion of the chimney is out of sight under the roof.

It has already been pointed out that when furring is used on the

thimble sides of brick chimneys, the brickwork should be extended outward to keep the thimbles from bending. This practice constitutes corbeling. Thimble corbeling is done on only one side of the chimney as shown by the sketch in (D) of Fig. 10. This sketch can be visualized by imagining that the view is taken in the direction of the arrow Y in the smaller sketch at (E).

By studying the sketch at (D) it can be seen that one side of that particular chimney is corbeled out 4″ above and below the thimble and that bricks *1, 2,* and *3* had to be cut or shortened in order to accomplish the corbeling on the side of the chimney shown. Where the thimble is set, the brick arrangement is as though there were no corbeling at all and the bricks are fitted around the thimble as previously described.

Chimneys which are built of solid concrete units or stone require no corbeling around the thimbles when such chimneys are furred.

Chimney Caps. Many kinds of concrete chimney caps can be purchased. They are made to fit the needs of chimneys having one, two, and three flues in many varieties of sizes and shapes. In setting a cap, it is placed on the last course of masonry work with a good mortar joint between it and the masonry work. If such ready-made caps are to be used, they must be designed and built to fit the flues and exterior dimensions of the chimneys.

Concrete caps can be made to fit any chimney by making the necessary forms and pouring the concrete. Fig. 36 illustrates a typical made - on - the - job wood form. Such a form can be used for pouring a cap for a two-flue chimney. This form can be made from 1″ boards with slats nailed across the top to keep the

Fig. 36. Wood Form for Pouring Chimney Cap for Two-Flue Chimney

flue forms in place. The entire form should be placed on a wood platform and a 1:2:4: concrete mix used for filling it. The mix should be stiff and should be well spaded around the edges of the form. In order to make the visible exterior sides smooth, a mixture of one part cement

and one part sand can be pressed against the forms before the regular mix is filled in.

After setting the caps in place, a mixture of equal parts cement and sand is applied on top of the cap and is shaped to the edges of the cap, as shown in Figs. 8 and 13. This should be troweled smooth and firmly against the flues.

Hoods and Pots. It is recommended that a mason who has had considerable experience be consulted regarding the construction of hoods and the installation of pots such as those shown in Figs. 14, 15, 28, 29, and 32.

Smoke Test. Every flue should be subjected to a smoke test before the chimney is furred, plastered, or otherwise enclosed. Such a test is conducted by building a paper, straw, wood, or tar paper fire at the base of each flue. When smoke is rising in a dense column, the outlets at the top of the chimney are blocked with a wet blanket. Any smoke escaping through the masonry indicates the location of leaks. Use of this test makes possible the repair of any chance leaks before the chimney is enclosed or put into actual use.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW
1. What the two main functions are of a chimney?
Answer. To carry away fumes and gases and to create a draft.

2. Why the draft in connection with chimneys is important?
Answer. Because the efficiency of any fuel-burning heating plant depends on sufficient draft. Draft causes fresh air to be sucked through the fuel beds of such plants, causing the fire to burn at the desired rate.

3. What two chimney faults are apt to be most common in chimneys not carefully designed and erected?
Answer. First, flues are apt to be too small, and second, the chimney is apt to be too short.

4. In what way a flue, which is too small, can cause trouble?
Answer. It retards the upward flow of fumes and gases due to the fact that its side surfaces offer too much resistance to the movement of fumes and gases. When too much resistance is present, the fumes and gases move too slowly up the flue to create draft.

5. How a draft is created?

Answer. The fumes and gases, as they enter the chimney, are hot. Any gas, when hot, expands and becomes lighter. When that happens, the gas seeks to rise. The rising fumes and gases in a well-designed and erected chimney create a suction in the chimney which tends to pull in air through the fuel beds of the heating plants. In that manner, the draft is created.

6. How much offset can be built safely in an interior chimney?

Answer. Not more than 30° off the vertical sides of the chimney below the offset.

7. Why soot pockets should be shallow?

Answer. Because if they are deep it would be impossible to clean out all the accumulated soot. The remaining soot then becomes a fire hazard.

8. Any method by which masons can prevent bricks or other materials from falling into flues when chimneys are under construction?

Answer. A cloth bag stuffed with straw to the extent that it fits tightly in flues, is pulled up in the flues as the masonry work progresses.

9. Why chimney foundations are so important?

Answer: Chimneys are very heavy and unless foundations of sufficient size are employed, a chimney is apt to settle and, as a result, crack or break, thus causing leaks which destroy draft and constitute fire hazards.

10. Why so many roof fires occur around chimneys?

Answer. If chimney flues are not lined or if the walls above roofs are not of double thickness, the wind is apt to crack open one or more mortar joints. Then, if the soot in such chimneys burns, flames can go through the joint cracks and attack combustible parts of roofs.

11. How thick the walls of interior brick chimneys should be when no flue lining is used?

Answer. At least 8 inches.

12. Why the walls of exterior chimneys which are exposed to outside air are made 8″ in thickness?

Answer. First, to give the chimneys greater stability, and second, to keep the interiors of the chimneys warmer in order not to chill the ascending fumes and gases. If the fumes and gases are chilled, they rise much more slowly and thus create less essential draft.

13. How flue linings can be cut without much risk of their breaking in an undesirable manner?

Answer. By filling the units of lining to be cut with damp sand and using a small chisel and light hammer to split the linings along the desired lines.

14. How far each brick course can be extended (corbeled) beyond the course just below it when building an offset in a chimney?

Answer. One inch.

15. Why it is impractical to have a furnace and stove both served by one flue?

Answer. Because either the furnace or stove (whichever smoke pipe is lower) does not receive enough draft.

16. What the minimum distance should be between the top of a smoke pipe and a ceiling?

Answer. Eighteen inches.

17. Why flues serving gas-burning appliances should be lined with a good lining?

Answer. Because, when gas is burned, the fumes and products of combustion contain acids which would tend to destroy the ordinary bricks and mortar in an unlined chimney.

REVIEW QUESTIONS

1. What is the most important function of a chimney?
2. Why is a round flue more efficient than a square or rectangular flue?
3. Why do tall chimneys function better than short ones?
4. Should unlined chimneys have the interiors of flues plastered?
5. Explain why the portions of interior chimneys above roofs should have their walls doubled in thickness.
6. Explain how to install the lowest piece of flue lining in a chimney.
7. Explain how to install a thimble in a chimney where the plaster is furred out from the chimney.
8. What is the purpose of a soot pocket?
9. What is a smoke test, what is its purpose, and how is it carried on?
10. What is a wythe?
11. Where are the highest chimneys necessary—in localities of high or low elevation?
12. Name two functions of a chimney hood.
13. How long should a unit of flue lining be when it is to be used for an 8½″ x 8½″ flue?
14. When increasing the thickness of chimney walls by corbeling, how much can one brick course extend out beyond the course just below it?
15. What mortar mix is recommended for chimney construction?
16. How high should a chimney top be above a flat roof?

Fireplace Design and Construction

QUESTIONS CHAPTER VII WILL ANSWER FOR YOU

1. *What are the types of fireplaces and what is the basic difference between them?*
2. *What are the various parts of a fireplace and how does each contribute to its working?*
3. *How is a fireplace built and what are the most important points to be remembered during construction?*
4. *What are the chief materials used in the building of a fireplace and what are the reasons governing the selection?*
5. *What are the factors determining fireplace design?*

INTRODUCTION TO CHAPTER VII

The development of the fireplace probably could be traced directly to the evolution of the chimney, for it was not until the principle of the flue had been discovered that a definite location was established for the heating and cooking fires within a residence. At least one aspect of the fireplace was important to its early users, for in Anglo-Saxon times, the king derived a portion of his revenue from *fumage,* or tax on smoke, which was levied on all hearths except those of the poor. In 1662 the English passed a similar law which was called the Hearth Tax. This two-shilling annual assessment was finally repealed in 1869 because of its extreme unpopularity.

The importance of the fireplace to Colonial Americans is a familiar story. Lack of shipping space and other factors resulted in these settlers adapting to their own requirements the fireplaces they had known in Europe. The greatest change perhaps was in the fireplaces which were built in New England. Because of the rigorous winters, the fireplaces and chimneys developed into massive structures which completely dominated the buildings both inside and out. These large fireplaces also dominated the lives of the people who built them for it was only natural, in view of the long, cold, winter evenings, that all family activity centered about the only source of warmth and light. Although stories of Lincoln's youth have become almost legendary in American history, there is little doubt that the greater part of his early education was obtained as he is so often pictured—reading, in various positions, by the light of the fireplace.

Due to the heritage and tradition of the fireplace, it is still a desirable feature of residences and other buildings where people congregate. Although its chief function has passed from one of utility to one of ornamentation, the

fireplace continues to be a part of the American home because of the informal, relaxed hospitality it suggests.

At first thought, the fireplace would seem to have little practical use in our era of efficient coal and oil stoves, unit heaters, and central heating. It is undeniably true that the fireplace is totally obsolete when considered as a sole source of heat for buildings located in northern sections of the United States. However, a well-designed, properly constructed fireplace can be used as an auxiliary source of warmth, especially in weather too cool for comfort, yet not cold enough to justify building a furnace fire.

In those parts of the country where winters are never severe, a type of fireplace is built which is far more efficient than the more common one. Its design and the materials used in its construction enable it to circulate the warmed air. When a system of ducts and registers is provided, this fireplace becomes a satisfactory method of heating near-by rooms in addition to the one in which it is located.

There is a definite place for the decorative, efficient fireplace in our mode of living. The material in this chapter has been prepared to assist the semi-skilled or inexperienced masonry worker in the building of such fireplaces. Both plain and modified varieties are discussed. Features of design and construction problems are explained. The many components of the fireplace and its flue are described and their purposes demonstrated. In brief, the chapter represents a thorough treatment of the design and construction of functional fireplaces and the problems that are encountered in this work.

FUNCTIONS OF THE FIREPLACE

Ordinarily, the fireplace is thought of in conjunction with living rooms. However, in the more expensive types of residences they are used also in dining rooms, bedrooms, dens, libraries, recreation rooms, and porches. They also may be used in public buildings such as restaurants for comfort and the air of informality they provide. Outdoor fireplaces in recreational areas such as parks and forest preserves are frequently provided for the use of the public in preparing picnic lunches.

A fireplace should be designed and constructed in such a way as to create a central point of interest and decoration in a room and should be built in accordance with the simple rules which will insure proper functioning. A fireplace should be of the size best suited to the space in which it is to be employed, both from the standpoint of appearance and operation. If it is too small, its decorative value is reduced and it may not throw out sufficient heat. If it is too large, it will dominate the space it occupies and give out too much heat as well as require too much fuel.

A fireplace can be beautiful and thus enhance any room. Also, it

can be depended upon to supply principal or supplementary heat. However, it must be carefully designed and properly built. A poorly designed or built fireplace may cause severe financial loss, keen disappointment, constant annoyance from soot and dirt entering living spaces, and many other undesirable conditions.

The purpose of this chapter is to explain and illustrate the simple principles upon which good fireplace design and construction depend. It will be shown how these principles are actually used in design and construction.

THEORY OF FIREPLACES

Warming Effect. The warming effect of a plain fireplace (one not having special heat distributing features in addition to a modern damper) is considerably less than is generally supposed. There are several reasons for this.

In the first place, warming effect is produced by *radiant* heat from the fire and from the hot back, sides, and hearth surrounding the fire. Heat radiation, like light, travels in straight lines. Unless one is within range of such radiation, little warmth is felt. Even if warmth is felt, it is apparent only on the side of the body which faces the fire. The other side of the body is cold. This fact can be explained more clearly using the example of bright sunshine on an early spring or autumn day when the temperature is low. If a person stands so that the sun's rays are upon him, the side of his body facing the sun will feel some warmth. The side opposite will still feel cold. The same is true in the case of heat radiation from a fireplace. The heat is limited to rather short distances from the fireplace with the result that not all areas, especially in large rooms, are reached by it.

Furthermore, heat from a fireplace is not circulated around the room by air currents. Where rooms are heated by steam radiators, circulation of the air is built up, which carries the heat from the radiator all over the room, gradually raising the room temperature. This does not occur with plain fireplaces, and, as a result, the room temperature does not rise appreciably.

The foregoing explanation can be visualized more easily by comparing the two sketches shown in Fig. 1. In (A) the heat from the fireplace radiates outward into the room for only a short distance. There is no

circulation to warm the air in the room. A person standing or sitting at point X would feel some heat but a person at point Y would feel none at all. In (B) the heat from the radiator circulates completely around the room; all of the air in the room is heated and a person sitting anywhere in the room would feel warmth on all sides of his body.

Still another reason why plain fireplaces provide little real heating is because air from the room in which the fireplace is located flows into the fireplace, through the fire, then up the chimney to the outside.
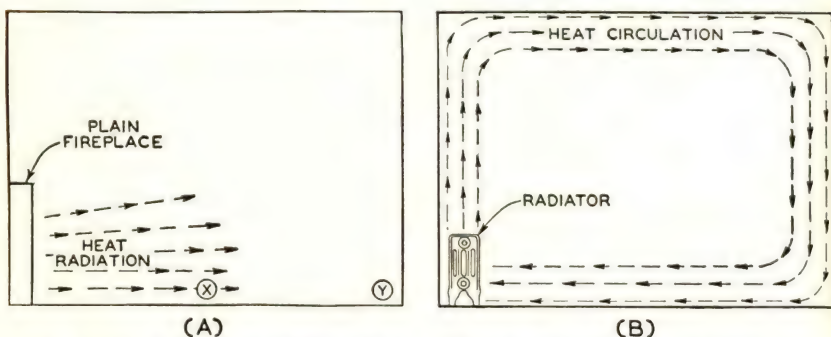
Fig. 1. Heat Radiation from Fireplace (A) and Heat Circulation from a Radiator (B)

Thus, much of the heat from the fire is carried up the chimney instead of being circulated in the room. As air enters the fireplace, it becomes heated, and because of this rises quickly through the chimney. This causes a suction of air from the room into the fireplace. The air drawn from the room is replaced by outside air which enters the room through cracks around windows and doors. This keeps the air temperature of the room below the comfort level. Tests conducted by the U.S. Bureau of Agricultural Chemistry have shown that approximately five times more air is drawn into a room in this manner than is required for good ventilation. Such excessive ventilation can easily cause chilling drafts. The same tests also have shown that a plain fireplace is only one-third as efficient as a good stove. Nevertheless, plain fireplaces have a place as an auxiliary to a heating plant and for their cheerfulness and charm. In milder climates, a plain fireplace may suffice as the sole source of heat. Also, certain materials often wasted may be utilized as fuel.

The disadvantages of plain fireplaces can be greatly lessened, however. Casings of heavy metal, provided with heating chambers, heat

inlets, and provisions for creating circulation are employed in what are called *modified* fireplaces. These devices make a fireplace much more efficient as a source of heat. Modified fireplaces circulate heat better than stoves, yet retain all the cheerfulness and charm of the plain fireplace.

Aside from the warming effect, one advantage claimed for the modified fireplace is that the correctly designed and proportioned firebox, manufactured with throat, damper, smoke shelf, and chamber, provides a *form* for the masonry, thus reducing the risk of structural failure and assuring a smokeless fireplace. This is a distinct aid to masons, especially if they have not had extensive experience in the design and construction of fireplaces.

Additional material on the modified fireplace is found in the section of this chapter which describes the kinds of fireplaces.

Essentials of Fireplaces. The design and construction of good fireplaces is within ordinary masonry skill if the functions and problems involved are thoroughly understood. These essentials are as follows:

1. Fireplaces must be designed and constructed to burn fuel properly so that all smoke goes up the chimney with none entering the room. To assure this desirable quality, the proper shape and relative dimensions of the combustion chamber must be correctly designed, the right location of the throat in its relation to the smoke shelf found, and the ratio of the flue area to the fireplace and opening area must be correctly calculated before construction is begun.

2. Fireplaces should be designed and constructed to yield the maximum warming effect and at the same time be firesafe.

3. These essentials can be assured if the size and shape of combustion chambers and construction units are correct.

Principal Parts of Plain Fireplaces. All principal parts of plain fireplaces are for the most part similar to those of modified fireplaces. (Any parts of modified fireplaces not explained at this point will be discussed under the section of this chapter dealing with the kinds of fireplaces.)

Figs. 2 through 6 inclusive show three typical, plain fireplaces plus some chimney details. These fireplaces are alike in general principles but have some differences in design and construction. By studying these illustrations, it will be possible to visualize the design and construction of these fireplaces and the following differences will be observed.
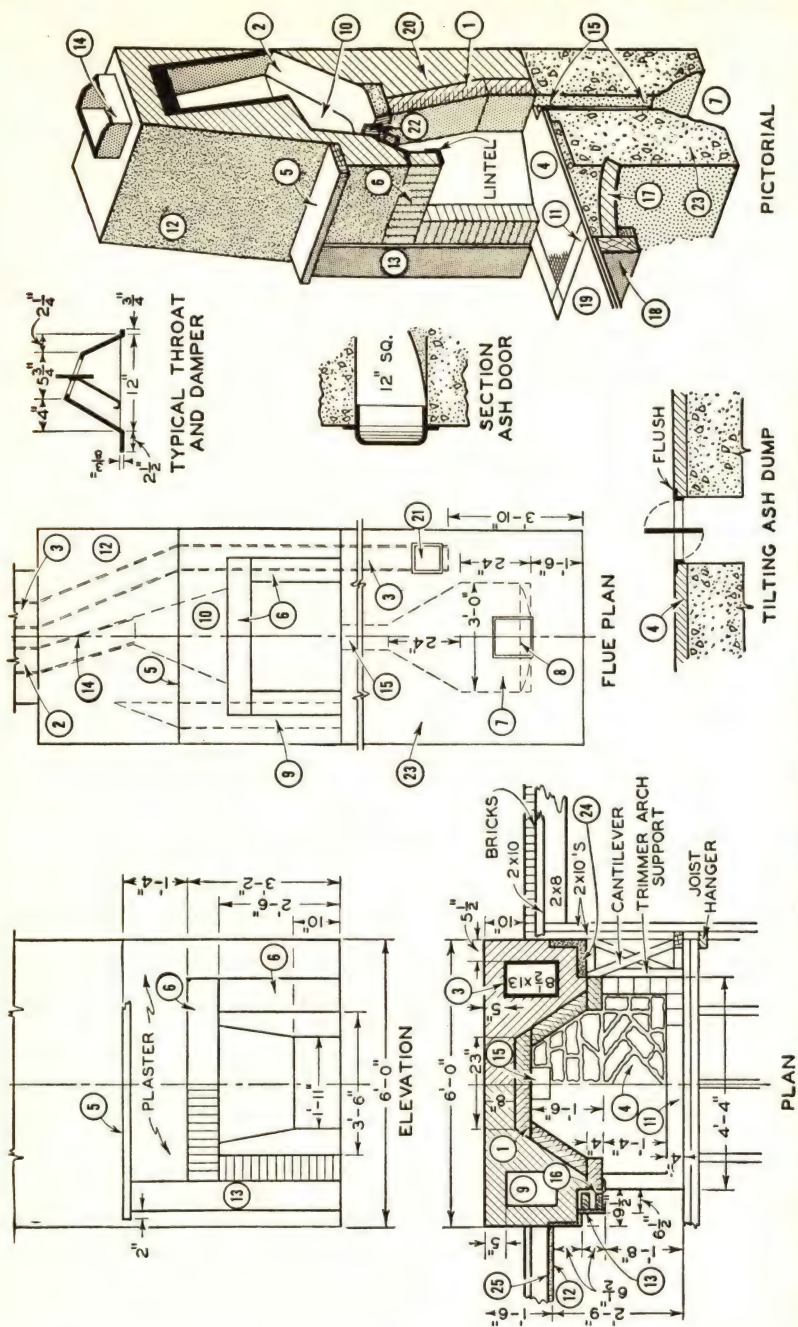
Fig. 2. Details of a Plain or Unmodified Fireplace
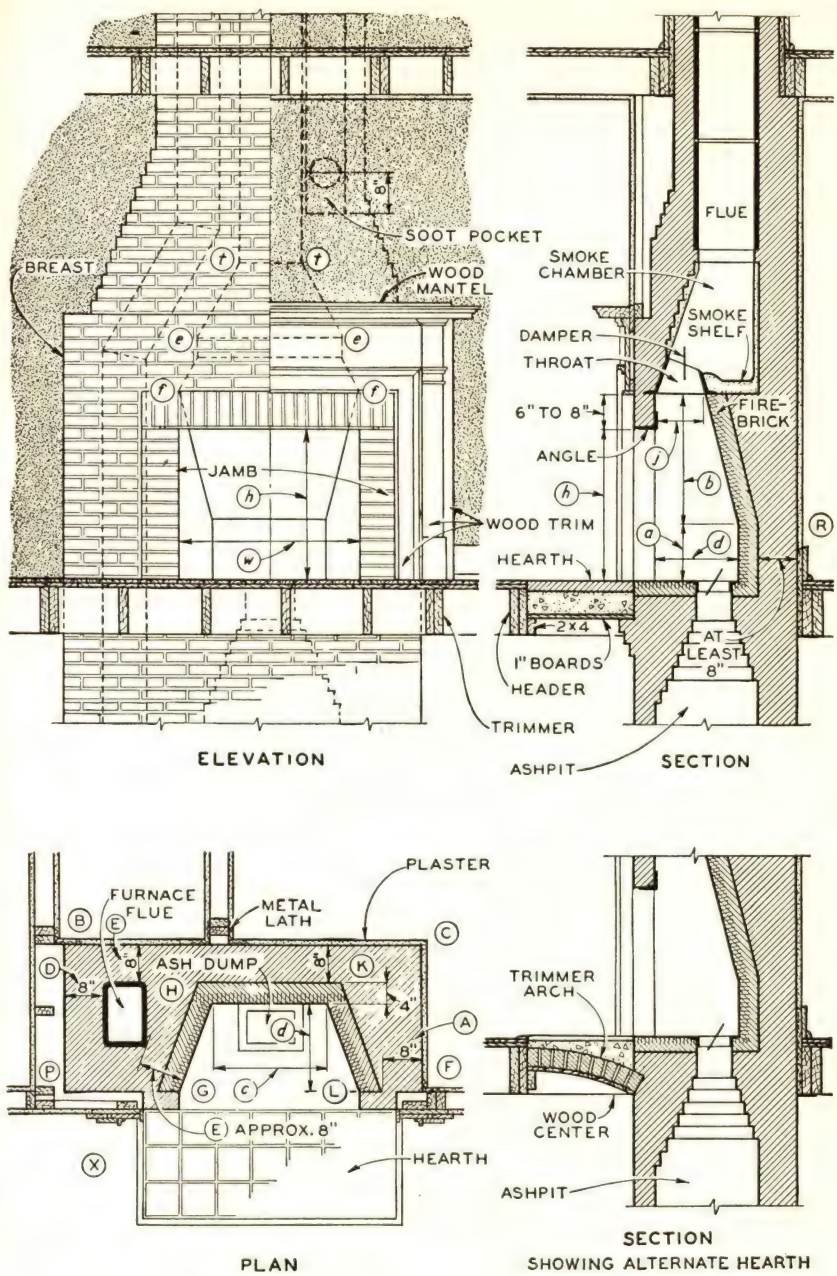
Fig. 3. Details of a Plain Fireplace and a Three-Flue Chimney

FOOTINGS FOR FIREPLACE FOUNDATIONS. Footings for fireplace chimneys are vital in preventing settlement, and cracks resulting from settlement. The design and construction of both brick and concrete foundations is described in Chapter III. The footings in Figs. 4 and 5 are made of concrete, whereas the footing in Fig. 6 is made of brick.
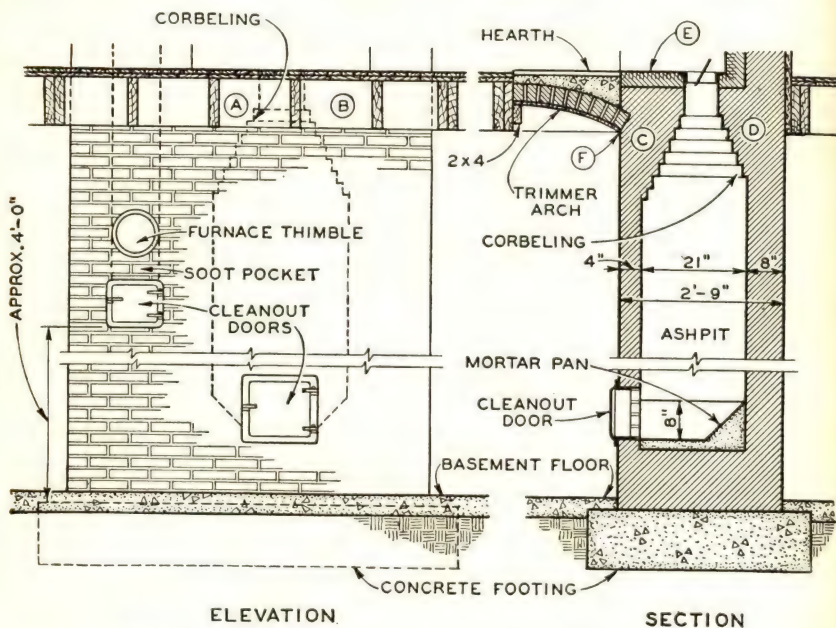
Fig. 4. Details for the Ashpit of the Fireplace Illustrated in Fig. 3

Note that the top surfaces of footings should be at a level which coincides with the under surfaces of basement floors.

ASHPITS AND DUMPS. Well-built fireplaces have ashpits and dumps which provide a means of clean and convenient disposal of ashes which accumulate as fuel is consumed. In Fig. 2, the plan, flue plan, and pictorial views show a typical ashpit and dump which are indicated by number *15*.

Note in the plan view of Fig. 2 that the ash dump is located at the back of the hearth, flush with the floor, and next to the rear side of the fireplace. The small detail under the flue plan in the same illustration shows a typical tilting ash dump. The dotted lines in the flue plan show

the shape of the ashpit. The shape and location of the ashpit is further illustrated in the pictorial view to be found at the right of Fig. 2.

Other typical ashpits and dumps are shown in Figs. 3, 4, 5, and 6. Note that while the shape of these dumps and pits varies somewhat, they are all in the same general position under the fireplace in the chimney.

CLEANOUT DOORS. Cleanout doors, as used in ash dumps, make possible the removal of ashes. See Fig. 2 (at *8* in the flue plan) and Figs. 4, 5, and 6. Note the positions and sizes of these doors. Sometimes such doors are called ashpit doors.

Fig. 5. Joist Framing Details around Fireplace Chimney Shown in Fig. 3

Cleanout doors at the bottoms of flues make it possible to remove accumulated soot. Cleanout doors serving this purpose are shown in Fig. 2 (see number *21* in the flue plan) and Figs. 4 and 6. Note that when cleanout doors are used with flues, they should be somewhat wider than the flues they serve.

HEARTHS. In Fig. 2 the hearth is indicated in the plan view by the flagstones and by number *4*. In the pictorial view the hearth is indicated by numbers *4* and *11*. Typical hearths also are shown in the plan and section views of Fig. 3, the section view of Fig. 4, the section view of Fig. 5, and in the section and pictorial views of Fig. 6. The charm or general appearance of a fireplace can be increased considerably by the design and construction of its hearth.

TRIMMER ARCHES. Trimmer arches are construction features which support those portions of the hearth extending beyond the fireplace. A typical trimmer arch is indicated by number *17* in the pictorial view of Fig. 2. This illustration demonstrates how the arch supports the extended portion of the hearth. Other examples of trimmer arches are shown in the section views of Figs. 3, 4, and 5 and in the pictorial and section views of Fig. 6.

JAMBS. Typical jambs are shown in Fig. 2, the elevation view in

Fig. 6. Elevation and Section Views of the Fireplace and Chimney Shown in Fig. 3

Fig. 3, and in Fig. 6. In Fig. 2 the jambs are indicated by the number 6. For this particular fireplace, face brick is specified for the jambs. They can be faced also with ornamental tile, stone, or plaster.

Occasionally, as in the case of Figs. 2 and 3, portions of jambs on either side and above the openings are extended about 4" in order that plaster and wood trim can be carried up to within 8" of the edge of the openings. This is purely a matter of taste and has no bearing on structural design.

LINTELS. Lintels are for the purpose of supporting the masonry work over the tops of the fireplace openings. The pictorial view in Fig. 2 illustrates the use of the lintel. It is the black symbol indicated by the arrow and is labeled. It can be seen that this lintel supports the weight of the masonry work above it. In the section view at the top of Fig. 3 the lintel is called an angle. Other examples of the lintel may be seen in the section and pictorial views of Fig. 6.

Lintels may be common angle irons, plain steel bars, or curved steel sections. Angles are shown in Figs. 2 and 3 and a curved section in Fig. 6.

THROATS. The throat of a fireplace is the passage through which smoke rises from the hearth or combustion area into the space just below the flue. The upper section view in Fig. 3 shows a typical throat. Others are shown in the section views of Figs. 5 and 6. By studying the flue plan and pictorial views of Fig. 2 it can be seen that the sides of the fireplace at a point just above the lintel gradually slope inward until they finally form the throat. Throats are important features of fireplaces. Unless they are properly designed and constructed, no fireplace will function correctly.

DAMPERS. Dampers regulate the draft and prevent excessive loss of heat through the flues. An ordinary damper (see detail at the right of the flue plan in Fig. 2) consists of a cast-iron frame with a plate hinged so that it may be opened or closed any desired amount. As indicated by number 22 in the pictorial view of Fig. 2, dampers are located in the throats of fireplaces. The upper section view in Fig. 3 and the section views in Figs. 5 and 6 also show typical dampers.

Dampers also prevent loss of heat through fireplace and chimney in winter when the central heating plant is in operation and when the fireplace is not in use.

PICTORIAL VIEW OF FIREPLACE

A

B

C

D

E

4" WALL

CHIMNEY BREAST

BRICK MANTEL

SMOKE CHAMBER

THROAT

LINTEL

DAMPER

TRIMMER ARCH

ASH DUMP

TERRA-COTTA FLUE LINING

F

G

CAST-IRON CLEANOUT DOOR
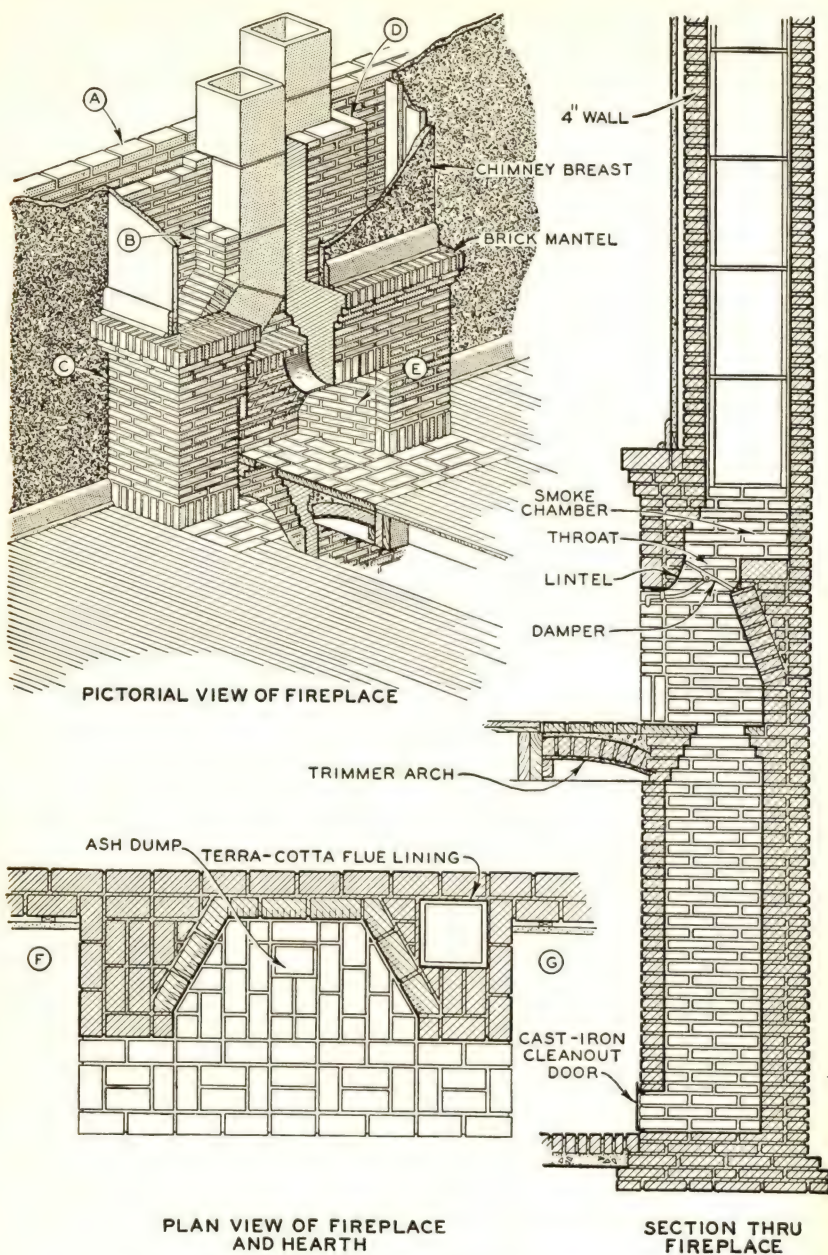
PLAN VIEW OF FIREPLACE
AND HEARTH

SECTION THRU
FIREPLACE

Fig. 7. Fireplace and Chimney Built Entirely of Bricks

A roaring pine fire in a fireplace may require the damper to be opened wide. On the other hand, a slow-burning hardwood fire might need but 1″ or 2″ of opening. Such throat adjustments could not be made without the damper. In addition to controlling the speed of burning, dampers prevent flies, mosquitoes, and other insects from entering the house through the chimney in the summer.

SMOKE CHAMBERS AND SHELVES. The smoke chamber is that portion of the fireplace which extends from the top of the throat to the bottom of the flue. Typical examples of the smoke chamber are shown in the pictorial view of Fig. 2 (number *10*), in the upper section of Fig. 3, and in the section views of Figs. 5 and 6. This chamber rapidly collects smoke from the fireplace just prior to the time it rises into the flues.

Smoke shelves prevent down drafts from descending into fireplaces. Without smoke shelves, fireplaces would emit smoke into the rooms in which they are located. Typical examples of smoke shelves are shown in the upper section view of Fig. 3 and in the section view of Fig. 5.

The enlarged detail in Fig. 7 showing the smoke chamber and shelf indicates the paths of smoke and drafts. The dashed line *A* is the path of smoke through the fireplace, through the damper and smoke chamber, and on up the flue. The dashed line *B* indicates down drafts and shows how they are turned upward by the smoke shelf. In this manner the smoke shelf prevents such drafts from carrying smoke down into the fireplace and at the same time helps to increase the draft up the flue.

FLUES. A thorough discussion of flues is given in Chapter VI on chimneys.

HEADERS. Floor joists must be framed around fireplace chimneys in such a manner as to support the floor safely. Note Fig. 8. It can be seen that joists *A, B,*
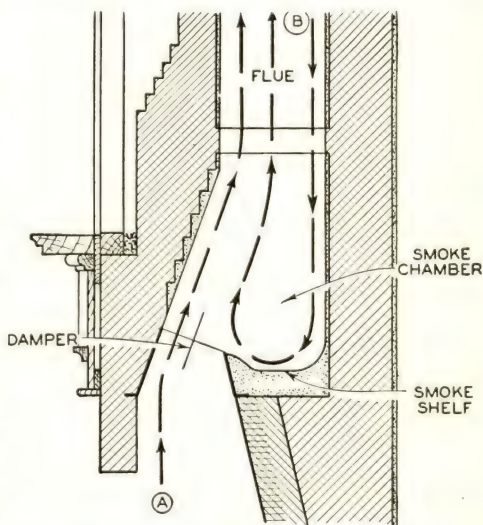
Fig. 8. Section Detail of Fireplace Illustrating the Return of Downdrafts up the Flues

C, and D had to be cut in order to make room for the fireplace chimney. In order to support these joists, the double headers are necessary. This is strictly carpentry work but a mason should understand the use of headers.

The framing shown in Fig. 8 is for the fireplace and chimney illustrated in the plan view of Fig. 3. Notice that the hearth does not extend all the way to the left-hand side of the chimney. Thus, the space marked X in Fig. 3 is framed as indicated by the cantilever in Fig. 8. Headers and cantilever construction also are shown in the plan view of Fig. 2.

MANTELS. Mantels, while not a necessary part of fireplaces, are frequently employed because of their decorative value. As such they add to the charm of a room because of the movable ornaments such as clocks and vases which can be placed upon them. Fig. 9 illustrates two typical fireplaces having mantels. The mantel is shown also at number *5* in the pictorial and elevation views of Fig. 2, in the upper section and elevation views of Fig. 3, and in the section and pictorial views of Fig. 6.

BLANK FLUES. As indicated by number *9* in the plan and flue plan views of Fig. 2, blank flues are occasionally built into fireplace chimneys. The purpose of these flues is to save the cost of the needless material and labor as well as to balance the weight.

FIREPROOFING. As shown in Fig. 8, about 2″ of fireproofing material should be placed between fireplace chimneys and all wooden or inflammable structural members. Even with good masonry work, fireproofing is worth while and should never be omitted.

CHIMNEY BREASTS. Chimney breasts are illustrated in the elevation views of Figs. 3 and 6.

It is possible there are other terms applied to fireplace and chimney parts which enjoy local usage in various sections of the United States. However, the parts which have been named bear standardized terms.

KINDS OF FIREPLACES

Plain Fireplace. The plain fireplace has been explained and illustrated in the foregoing pages. It is the fireplace which has been used to the greatest extent in the past and is still popular where a fireplace is required for its decorative value and only occasional use as an auxiliary source of heat.

Courtesy of American Builder

Fig. 9. Typical Fireplaces Illustrating the Decorative Value of the Mantel
Courtesy of Curtiss Companies Incorporated

Modified Fireplace. When the primary function of a fireplace is to supply heat, the modified fireplace is employed. The principal difference between the two types is the use of a heavy metal casing along with other modifications in the fireplace proper. In addition, provisions are made to insure the circulation of warm air.

Fig. 10 illustrates the details of a typical modified fireplace in a sectioned pictorial drawing. The metal casing composing the fireplace
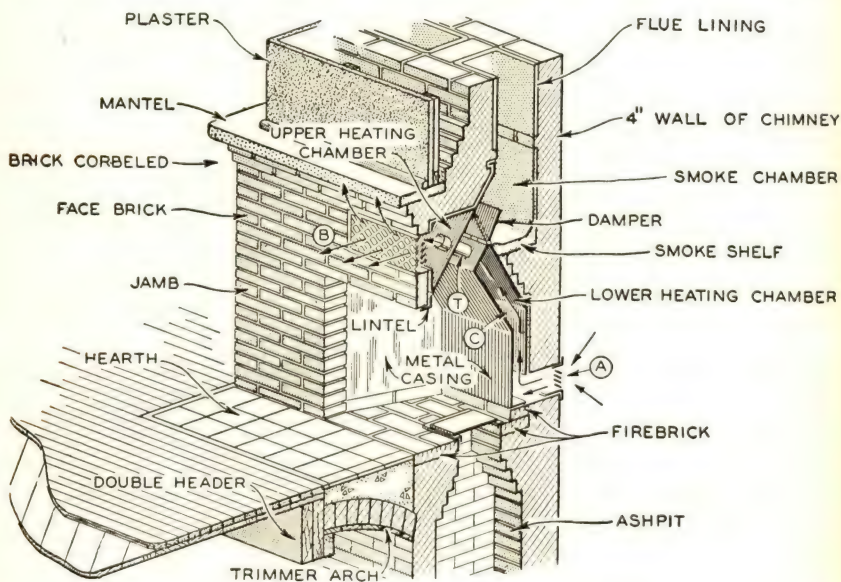
Fig. 10. Details of a Modified Fireplace

proper can be seen. A slightly different presentation which is perhaps more easily visualized is shown in Fig. 11. The basic principle governing the use of such casings is that they absorb and radiate a greater quantity of heat than masonry work. Thus, more heat from the fire is utilized for heating.

The means by which the warm air is circulated is as follows:

Note the lower and upper air chambers near the back of the fireplace and above the lintel in Fig. 10. These chambers are connected by several tubes as shown at T. It is evident that these chambers and tubes are in actual contact with fire and hot smoke. Being metal, they absorb a great deal of heat. As the air in the lower chamber C, the air

in the tubes, and the air in the upper chamber becomes heated, it rises and goes out through the heat outlet at *B* into the room. This upward movement of air through the chambers creates a suction in the lower chamber which draws in cold air from the exterior inlet shown at *A*. As this incoming air is warmed by heat radiated from the metal walls of the chamber, it rises to the tubes where its temperature is increased by heat radiated from them. The additional heat causes the air to con-
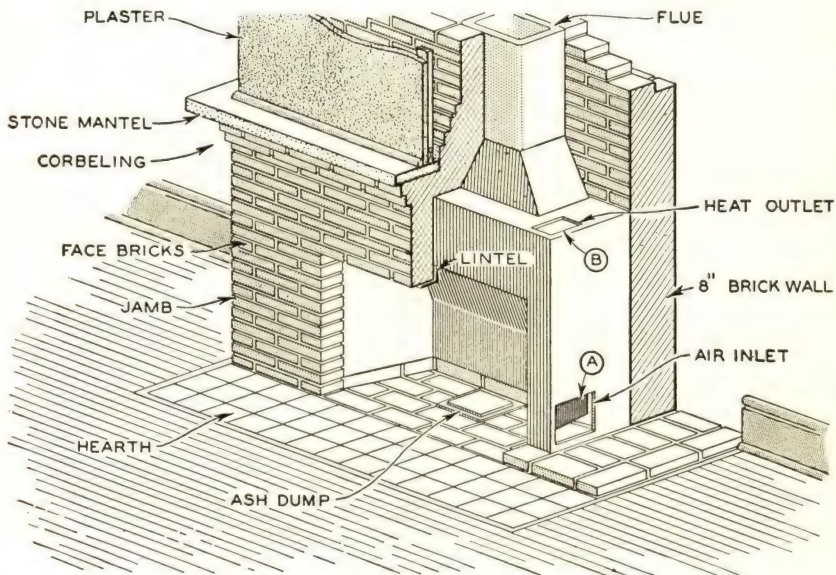
Fig. 11. Another Variety of the Modified Fireplace

tinue its rise until it enters the upper smoke chamber where its temperature is increased still further with the result that it flows out through the heat outlet into the room. This process, which is continual, circulates heat rather evenly throughout the room in which the fireplace is located.

The fireplace shown in Fig. 11 employs a somewhat different application of the circulation principle explained in the previous paragraph. In this fireplace the air is not taken from the exterior, but through an inlet, *A*, from the room that is being warmed. The air is warmed as previously explained, rises, and is discharged into the room from outlet *B*. This process tends to create better circulation of warmed air in the

room than when the inlet is located on the exterior. Also, the air leaving the outlet is warmer because, in coming from the room instead of the exterior, it is warmer to start with.

Fig. 12 shows the possible positions for inlets and outlets for a modified fireplace somewhat similar in appearance to the plain fireplace illustrated in Fig. 6. Letters *A, B, C,* and *D* indicate the possible positions for inlets and outlets if both were desired on the front of the fireplace. Letters *E* and *F* indicate where inlets and outlets could be placed at the ends of such fireplaces. Both inlets and outlets could be placed at either end.

FRONT VIEW   END VIEW
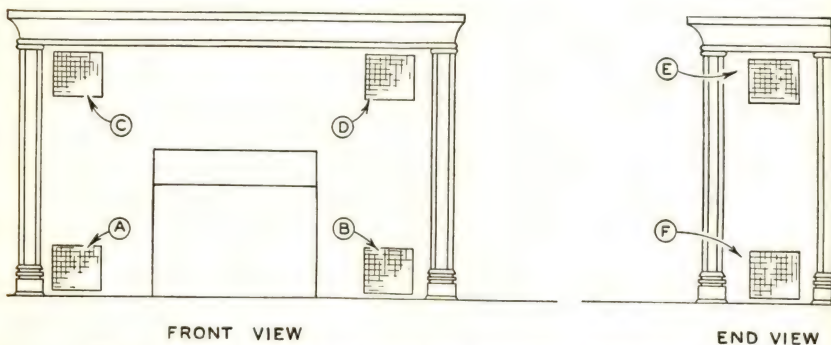
Fig. 12. Possible Positions for Inlets and Outlets in a Modified Fireplace

Fig. 13 shows some of the ways in which ducts (warm air pipes which correspond to outlets) can be run when modified fireplaces are to be used to heat more than one room. The ducts marked *1, 2,* and *3* are for second floor rooms above the fireplace. In such instances, baseboard registers are used. The duct marked *4* shows a possible method of running a cut up into an attic and then to the ceiling of some room a considerable distance from the fireplace. The openings marked *5, 6, 7,* and *8* are outlets such as explained in connection with Fig. 12. The rectangle marked *6* indicates that one central outlet may be used as illustrated in Fig. 10. In any event, no matter what ducts or outlets are used, the inlets near the floor must be employed. For these inlets (*A* and *B* in Fig. 12) a duct must be provided to connect them with the allied openings in the metal casings as shown in Fig. 13.

The metal casings used in modified fireplaces are made by various manufacturers ready for assembly and installation. Each manufac-
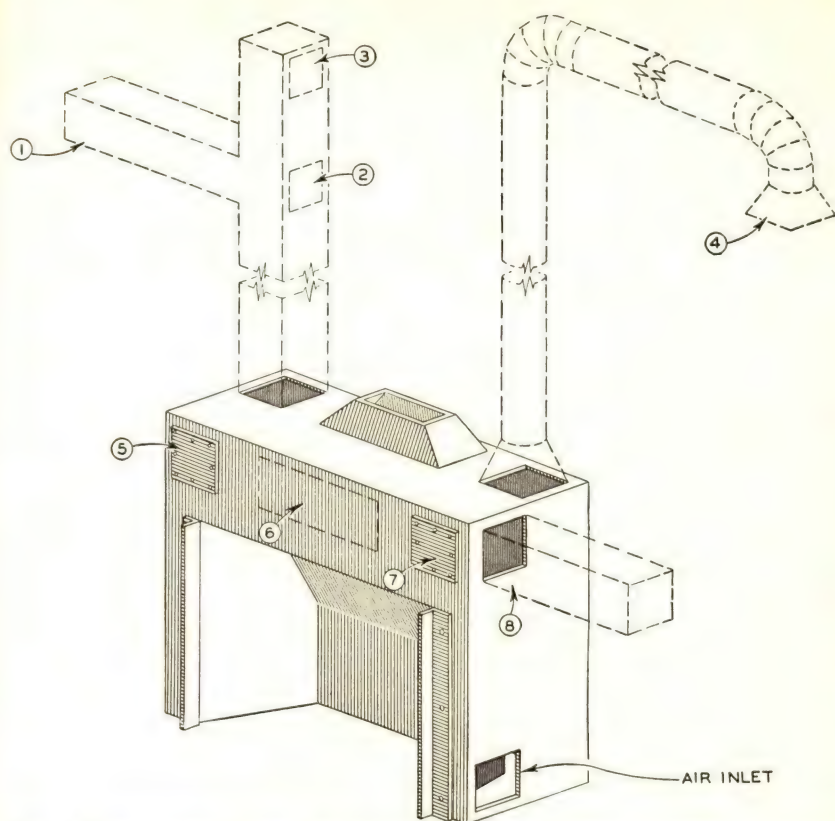
Fig. 13. Possibilities of Ducts Used in Conjunction with Modified Fireplace for Heating Other Rooms

turer's casing is somewhat different, but in general they are quite similar.

FIREPLACE DESIGN

Selection. There are several important points to be considered in the planning of a fireplace before the actual designing can be started. These decisions lead to the actual design.

First, the use of the fireplace must be considered and the question decided as to whether it must serve as a principal source of heat (like a modified fireplace) or merely enhance the appearance of a room where little supplementary heat is required. From the study of the foregoing explanations and illustrations in this chapter, it can be readily

understood that the dimensions and some features of design are different for plain and modified fireplaces.

SIZE. There are several significant factors governing the sizes of fireplaces which will be considered in order of their importance.

General Considerations. Thirty inches is a practical height for any fireplace if the width of the opening is less than 6 feet. Openings approximately 30″ to 36″ wide are usually made with square corners. The higher the opening is made, the greater the chance for a smoky chimney. In general, the wider the fireplace opening, the greater should be the depth. A shallow fireplace will throw more heat but requires smaller pieces of fuel. In small fireplaces, a depth of 12″ will permit good draft if the throat is properly constructed. However, a depth of from 16″ to 18″ is recommended especially as a means of preventing brands from falling out on the floor beyond the hearth. Second floor fireplaces are as a rule smaller than fireplaces located on the first floor. This is true because the chimney width need not be as wide and because the flue height is less than for first floor fireplaces.

Brick fireplaces and their chimneys are in general smaller than those built of stone. This is because of the added wall thicknesses required in connection with the use of stone. A brick fireplace can generally be built quicker and at less cost than one built of stone.

Widths of Openings. The type of fuel to be burned is an important consideration and should be decided upon early in the planning stage. For example, if cordwood (4′ 0″ long) is cut in half, a 30″ wide fireplace opening is sufficient. If coal is to be burned, a fireplace opening of less width will be satisfactory. Figs. 9, 14, and 15 show fireplaces having openings of approximately 30″ width. Fireplaces having an opening from 30″ to 36″ generally are suitable for rooms having floor areas up to 400 square feet. Larger rooms should have proportionately larger fireplaces. This general rule applies to both plain and modified fireplaces.

Typical widths for fireplace openings are shown in the first column of Table I. For example, the widths of the openings (see *w* in the plan view of Fig. 3) run all the way from 24″ to 72 inches.

Heights of Openings. In the second column of Table I are shown the recommended heights (see *h* in the top section view of Fig. 3) for various widths of openings. For example, an opening 30″ wide should be

Fig. 14. Modern Treatment of Fireplace in Which Mantel Has Been Omitted
Courtesy of American Builder
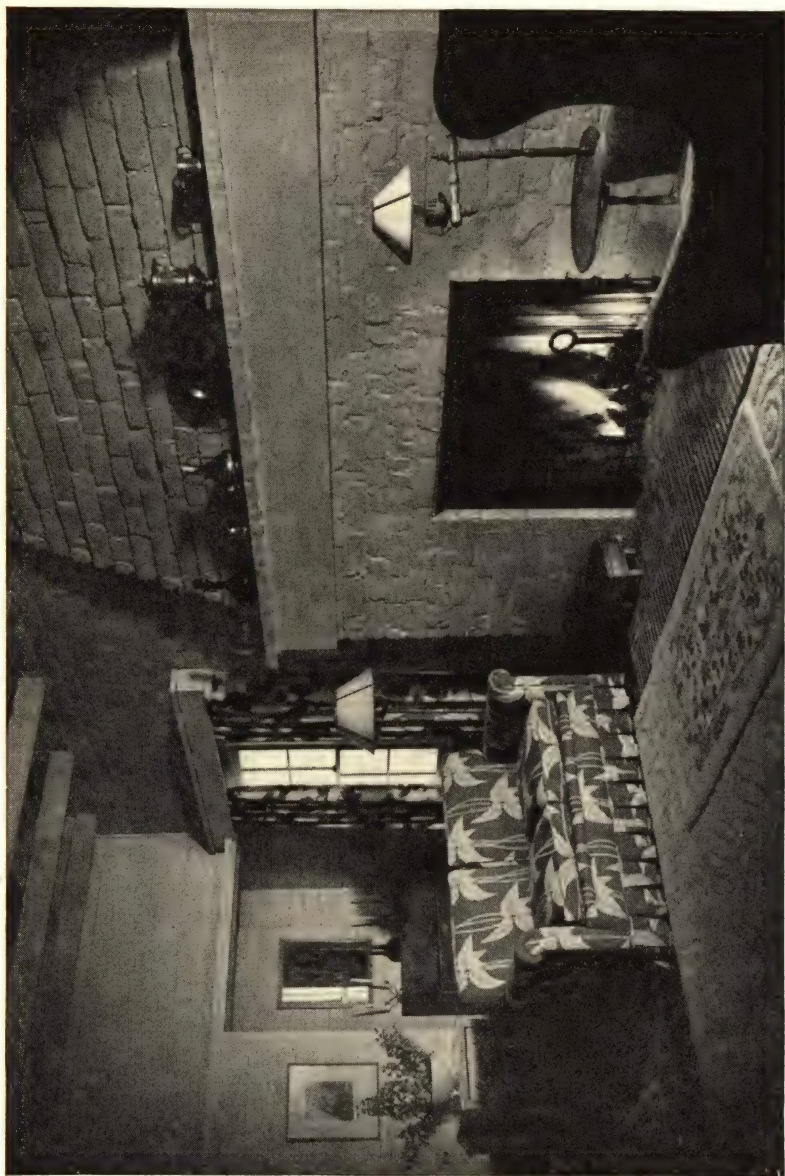
Fig. 15. Fireplace with Traditional Styling Given Modern Touch by Painting
Courtesy of American Builder

TABLE I. RECOMMENDED DIMENSIONS IN INCHES FOR PLAIN FIREPLACES*

Opening		Depth, d	Minimum Back (Horizontal) c	Vertical Back Wall, a	Inclined Back Wall, b	Outside Dimensions of Standard Rectangular Flue Lining	Inside Diameter of Standard Round Flue Lining
Width, w	Height, h						
24	24	16–18	14	14	16	8½ x 8½	10
28	24	16–18	14	14	16	8½ x 8½	10
24	28	16–18	14	14	20	8½ x 8½	10
30	28	16–18	16	14	20	8½ x 13	10
36	28	16–18	22	14	20	8½ x 13	12
42	28	16–18	28	14	20	8½ x 18	12
36	32	18–20	20	14	24	8½ x 18	12
42	32	18–20	26	14	24	13 x 13	12
48	32	18–20	32	14	24	13 x 13	15
42	36	18–20	26	14	28	13 x 13	15
48	36	18–20	32	14	28	13 x 18	15
54	36	18–20	38	14	28	13 x 18	15
60	36	18–20	44	14	28	13 x 18	15
42	40	20–22	24	17	29	13 x 13	15
48	40	20–22	30	17	29	13 x 18	15
54	40	20–22	36	17	29	13 x 18	15
60	40	20–22	42	17	29	18 x 18	18
66	40	20–22	48	17	29	18 x 18	18
72	40	22–28	51	17	29	18 x 18	18

*Letters at heads of columns refer to Fig. 3.

28″ high. Note that the opening height is taken as the distance from the hearth to the lintel.

Depths of Openings. The third column of Table I shows the recommended depths for fireplaces (see d in the upper section view of Fig. 3) having openings of various widths and heights. For example, a fireplace having on opening 30″ wide and 28″ high should have a depth of at least 16″ to 18 inches.

Back Widths. In the fourth column of Table I are shown the recommended minimum back widths (horizontal) (see c in the plan view of Fig. 3) for fireplaces having certain other dimensions. For example, when a fireplace opening is 30″ in width, 28″ high, and 16″ to 18″ deep, the horizontal back width should be at least 16 inches.

Back Heights. The fifth column of Table I gives the recommended heights for vertical backs (see a in the top section view of Fig. 3) for fireplaces having certain other interior and opening dimensions. A fireplace having an opening 30″ wide, an opening height of 28″, a depth of 16″ to 18″, and a horizontal back dimension of 16″, should have a vertical back dimension 14″ in height.

In like manner, the height of the inclined backs (see b in the top section view of Fig. 3) for chimneys is shown in the sixth column of

Table I. The height of the inclined back for the chimney under discussion is shown to be 20 inches.

RECTANGULAR FLUE SIZES. From column 7 of Table I the recommended flue size for the 30″ width fireplace is seen to be 8½″ x 13 inches. Or, as was demonstrated in Chapter VI, the cross-sectional area of a fireplace flue should be equal to $\frac{1}{12}$ the area of the fireplace opening. If a fireplace opening is 30″ wide and 28″ high, its area is 30 x 28, or 840 square inches. Standard sizes of flue lining sometimes do not have a cross-sectional area which exactly matches the fireplace opening area in the ratio just indicated. In such a case, a flue size having an area slightly in excess of $\frac{1}{12}$ the area of the fireplace opening should be selected.

ROUND FLUE SIZES. Column 8 in Table I shows recommended round flue sizes for fireplaces having certain dimensions.

THROATS AND DAMPERS. At j, in the upper section of Fig. 3, is shown the throat. Correct throat construction contributes more to the efficiency of a fireplace than any other single feature except the flues. There must be a constriction at the throat in order to maintain good drafts. The cross-sectional area of the throat should not be less than the cross-sectional area of the flue. Their length should be equal to the width of the fireplace opening. The sides of the fireplace should be vertical up to the throat opening (see ff in the elevation view of Fig. 3). Throats (see upper section view in Fig. 3) should be set 6″ to 8″ above lintels and should not be more than 4″ to 6″ wide. Starting 5″ above the throat (see ee in the elevation view of Fig. 3), the sides should be drawn in at tt to equal the flue area. If dampers are installed (see typical damper illustrated at left of pictorial drawing in Fig. 2) the widths of the openings at the throats will depend upon the frames of the dampers—the width of the throat being regulated by the hinged covers of the dampers. If dampers are omitted, the openings should not be more than 4 inches.

Manufacturers of fireplace equipment can supply catalogues and other information in which they specify sizes of throats and dampers for various sizes of fireplaces. They will always assist any mason in selecting proper dampers and throat sizes for any given fireplace.

SMOKE SHELVES AND CHAMBERS. Smoke shelves are made by setting the brickwork back at the tops of throats to the lines of flue walls for

the full lengths of throats. Their depth may vary from 6″ to 12″ or more, depending on the depth of the fireplace.

Smoke chambers constitute the spaces extending from the tops of throats (see *ee* in the elevation view of Fig. 3) up to the bottom of the flue proper (*tt*) and between the side walls. The walls should be drawn inward 30° from the vertical after the tops of the throats (*ee*) are passed and smoothly plastered with cement mortar not less than half an inch in thickness.

LINTELS. Lintels of 3½″ x 3½″ x ¼″ angles, or ½″ x 3″ x 6″ flat or curved bars, are generally used for fireplaces having openings not greater than 4 feet. For greater widths, the lintels should be designed using the principles described in Chapter IV.

JAMBS. For fireplace openings up to 36″ in width, the jambs should be from 12″ to 16″ or more, depending on whether flues from below the fireplace must be carried in the same chimneys. Note the plan view in Fig. 3. On the right-hand side where there is no flue, the jamb is approximately 12″ wide. Because of the flue on the other side, the jamb is approximately 20 inches. In Fig. 6 the jambs are approximately 16″ wide.

MANTELS. The design of mantels, if they are to be used, is purely one of taste. Brick mantels such as shown in Fig. 6 are attractive, especially when the jambs of the fireplace are entirely visible and faced with brick. When wood mantels similar to the one shown in Fig. 2 are desired, they and the wood trim to accompany them can be purchased ready to install from woodworking mills. For example, the two fireplaces shown in Fig. 9 have wood mantels. The mantels and the wood trim that goes with them are purchased complete and ready to assemble and install. Stone mantels such as shown in Fig. 11 can be purchased ready to install or can be made at any stone supply yard.

ASHPITS AND DUMPS. Ash dumps (see detail in Fig. 2 of tilting ash dump) are usually 3″ x 8″ with the long dimension parallel to the back of the fireplace. However, any other dimensions, the total of which is about the same as the recommended 3″ x 8″, are satisfactory. The door should be constructed so that it will tilt and should be flush with the hearth. These doors can be purchased in various shapes ready to install from fireplace parts manufacturers.

Ashpits, as shown in Figs. 4, 5, and 6, should be large as a means of

avoiding clogging and in order to save on the use of brick and mortar. The width should be about 2′ 3″ and the thickness about 21″ when used in conjunction with fireplace openings having widths up to 42″ and depths up to 18 inches. For larger fireplaces, the pit dimensions should be slightly greater. Whatever size pit is used, the wall marked *M* in the section view of Fig. 5 should never be less than 4″ and the widths, marked *R* and *P* in the elevation view, not less than 16 inches.

The tops of ashpits can be corbeled starting at the hearth level as shown in the section view of Fig. 6 or somewhat below the hearth as shown in the section view of Fig. 4.

At the bottoms of ashpits it is a good policy to build up a mortar pan as shown in the section views of Figs. 4 and 5. This facilitates the removal of the ashes. However, if desired, the bottoms of the ashpits can be left flat as shown in the section view of Fig. 6.

CLEANOUT DOORS. These metal doors are purchased from fireplace parts manufacturers and are ready to install as the masonry work is laid up. They can be purchased in various sizes to fit any requirement —flue bottoms, ashpits, etc.

FIREPLACE LININGS. The firebrick for fireplace linings should be laid up so as to make the lining a full 4″ in thickness. In other words, the firebrick should be laid flat and not on edge. When laid flat with the long side exposed, there is less danger of their falling out of the wall. It is best to lay firebrick in fire clay mortar. The sides, vertical backs, and inclined backs should all have such a lining.

Firebrick. This material is a type of brick which is especially made to withstand contact with heat. Ordinary brick do not have this quality to the extent to permit their use in place of firebrick. This is an important point to remember in the construction of fireplaces. Typical brick fireplace linings are shown in the plan and pictorial views of Fig. 2.

TRIMMER ARCHES. As indicated in the two section views of Fig. 3, there are two methods of handling the design of the trimmer arch. In the upper section view, the arch is really flat and is supported at the fireplace end by corbeling and at the header end by a 2 x 4 block. About 5″ of concrete is poured and the hearth surfacing laid on the concrete. Perhaps the most common trimmer arch is the one shown in the lower section view of Fig. 3. The arch is laid up using brick which are sup-

ported at the fireplace end by being recessed into the ashpit wall. They are supported at the other end by the header. Concrete is poured as explained for the flat arch. The illustration shows the position of the arch. The length of such arches depends on the hearth dimensions.

HEARTHS. The hearth should be flush with the floor of the room the fireplace is in. They should project at least 16″ from the jambs and should be of brick, stone, terra cotta, tile, or any other fireproof material. Their thickness, including the trimmer arch, should be not less than 5 inches. The length of the hearth should not be less than the width of the fireplace opening plus 16 inches.

EXTERIOR FINISH OF FIREPLACES. The selection of exterior finish is a matter to be decided upon after a study has been made of the surrounding trim and ornamentation. For example, in recreation rooms, a fireplace such as shown in Fig. 6 might be used. Fireplaces such as those shown in Figs. 2, 9, 14, and 15 are more suitable for living and dining rooms. Examples of fireplace exterior finish can be obtained from woodworking mills, fireplace parts manufacturers, and current household magazines.

EXTERIOR CHIMNEY SHAPES. The shapes of exterior fireplace chimneys generally change above the second floor level or at points somewhat below that level, since only a width large enough to house the flues is necessary above the fireplace. The elevation view of Fig. 3 illustrates this point. Other examples can be seen in Figs. 27, 28, and 30 of Chapter VI.

INTERIOR CHIMNEY SHAPES. The shapes of interior chimneys also change at or just below the second floor level. Note in Fig. 6 that the point designated by letter A in the pictorial sketch is almost at the second floor level. The chimney at B is already much narrower than that at C. The other side of the chimney has likewise been narrowed so that width DB is just enough to house properly the two flues. By making the chimneys just wide enough to house the flues, once they have been built up above the smoke chambers, a great saving in material is achieved as well as the saving in space in second floor rooms.

CHIMNEY WIDTHS AND THICKNESSES. In this discussion the width of a fireplace chimney is taken as the distance BC in the plan view of Fig. 3 or as indicated by the 6′ 0″ dimension near the bottom of the chimney in Fig. 5.

Brick Chimneys. The width of a fireplace chimney from the foundation to a point somewhere above the fireplace must be wide enough to include the fireplace, one or more flues, and ample chimney walls. If Fig. 5 is carefully studied it will be seen that the width of the chimney between points *A* and *B* is greater than at any point above *B*.

There is no standard theory about chimney widths just above and below fireplaces except that they should have pleasing proportions and should be strong and firesafe. Study the plan view in Fig. 3. Here, the fireplace, one flue, and the chimney walls make up the entire width. Note that distances *A*, *D*, and *E* are 8 inches. Walls of this thickness are recommended over the thinner walls shown in the plan views of Figs. 2 and 6. The walls shown in Fig. 2 are only 4″ thick. While they are not unsafe, they require considerable brick cutting and laborious construction. The walls shown in the plan view of Fig. 6 are probably safe and strong and require little cutting of brick. However, the walls between the flue and the fireplace surface and between the flue and the surface of the exterior of the chimney are just one brick width or 4″ in thickness. This is much thinner than recommended in terms of safety from fire.

In Fig. 5 note the thickness of the fireplace chimney between points *G* and *H* in the section view. This thickness is indicated by the 2′9″ dimension shown near the base of the fireplace. The thickness of a fireplace chimney must be sufficient to include the fireplace and at least 8″ of masonry work between the rear face of the fireplace and the exterior face of the chimney. The plan view of Fig. 6 shows 8″ of masonry which just meets the requirements of the rule. In the plan view of Fig. 3 a thickness of 8″ plus another 4″ is shown. This constitutes a much better type of construction which is superior in every respect and increases fire protection immeasurably.

Stone Chimneys. For all fireplace chimneys constructed of stone, the walls should be at least 12″ in thickness between fireplaces and exterior surfaces.

METAL FIREPLACE CASINGS. The metal casings for modified fireplaces can be purchased ready to assemble and install from various manufacturers. Most of these manufacturers have a range of sizes from which selections can be made to fit the needs of the rooms to be heated. All of them will supply free catalogues, sales service, and instruction

sheets or manuals relative to the proper selection and installation of their casings.

As shown in Figs. 10 and 11, the metal cases are surrounded by masonry work. This means that definite dimensions must be followed in designing the openings, jambs, walls, ashpits, etc., in order that the casings can be set into place at the proper time during construction and the masonry work laid up around and above them. All such dimensions are given in the manufacturer's catalogues in somewhat the same manner as the dimensions for plain fireplaces.

Design Procedure for Plain Fireplaces. As a general rule, the mason will seldom be called upon to design the fireplace he builds. However, changes in building plans to include a fireplace and other such exceptions make this knowledge essential. In addition, a more complete understanding of the problems involved in building the fireplace will be possible if it is known how they are planned or designed. The recommended procedure for building a plain fireplace similar to the ones shown in Figs. 3, 4, and 5 is as follows:

1. Based on the floor area of the room in which the fireplace is to be located, select the opening size and other related dimensions from columns 1 through 6 in Table I.

2. Make a scale drawing showing the plan arrangement of the fireplace similar to *GHKL* in Fig. 3. Remember that the back of the fireplace is considerably narrower than the opening width as indicated by the difference between the dimensions in columns 1 and 4 of Table I.

3. Draw in the lines representing the firebrick fireplace lining and a second set at least 8″ beyond. These lines represent the back of the chimney (*BC* in the plan view of Fig. 3). This line can be made any length at this stage since it is just a means of locating the chimney back.

4. Next, the furnace flue is drawn in. In the best types of construction, this flue is at least 8″ from the back of the chimney and is not nearer than 8″ to the side of the fireplace.

5. Draw a line such as *PG* in the plan view of Fig. 3, representing the left-hand jamb and breast. Following this, a line is drawn which represents the left-hand end of the chimney such as line *PB* in Fig. 3. This line must not be nearer than 8″ to the furnace flue.

Note: Flues can be nearer than 8″ to the sides and backs of fireplaces but this practice is not recommended when the 8″ distance is possible. An example of a flue which does not adhere to this recommendation is shown in Fig. 6.

6. Draw the jamb and end of the chimney on the right side, making the end at least 8″ from the firebrick lining.

7. Check the over-all dimensions to make certain that whole bricks can be laid up without any cutting being necessary. Such planning is shown to good

advantage in the plan view of Fig. 6. In the event whole bricks cannot be used, the dimensions may have to be changed a bit in order to accomplish this.

8. Following this, the hearth is drawn in, and the ash dump and projecting jambs located.

9. Next, make a section drawing of the fireplace according to dimensions *h*, *d*, *a*, and *b* from Table I, similar to the upper section view in Fig. 3 and the section view in Fig. 5.

10. Draw in the ashpit and foundation, and the trimmer arch.

11. Draw in the throat using the dimensions of the damper selected. Draw in the smoke chamber and shelf following the directions given relative to *ff*, *ee*, and *tt* in connection with the elevation view of Fig. 3.

12. Draw an elevation view of the fireplace and chimney and show the flues by means of dashed lines.

13. Check over all three drawings to make certain that all parts of each correspond exactly with the same parts in the other drawings.

14. Draw in the dimensions of all parts in all three sketches and make sure they check accurately against one another.

Note: The design of chimneys above fireplaces is fully discussed in Chapter VI.

Design Procedure for Modified Fireplaces. The methods involved in designing modified fireplaces are the same as described for plain fireplaces except that dimensions and other special instructions must be taken from manufacturers' instruction sheets and/or manuals.

Drawings such as those just described are a necessity when designing a fireplace. They will aid in avoiding errors and faulty design and act as a guide during the actual construction.

FIREPLACE CONSTRUCTION

If fireplaces and their accompanying chimneys are parts of residences or other small buildings which have been designed by architects, most of the necessary detail drawings will be shown in the working drawings. These details, which are parts of plan, elevation, and section drawings, usually show the principal dimensions for fireplaces and chimneys as well as their exact locations in the buildings of which they are a part. The architect's written specifications also describe such items as dampers, trimmer arches, ash dumps, and the other fireplace components. However, architect's drawings sometimes do not show the exact details pertaining to such features as smoke chambers and shelves, corbeling, and other important fireplace components. In such cases the mason must rely on his knowledge of fireplace construction in order to obtain satisfactory results in building them. The foregoing

parts of this chapter have been aimed at helping inexperienced masons to acquire such knowledge.

In plans which have been drawn by architects, the exact locations of fireplace chimneys are shown in all floor plan drawings including the basement. The mason studies these plans and determines from them the exact place to start construction. If the mason must work without architect's plans or if such plans are inadequate in the presentation of information concerning the fireplace and chimney, he must make his own sketches showing the fireplace and chimney size and location, and their relation to the various floors, walls, and roof in the building of which they are to be a part. Such drawings are a great aid from the standpoint of construction and are the means of preventing mistakes in the masonry work.

Building Footings. The process of locating and building fireplace and chimney footings (sometimes called foundations) is fully explained in Chapters II and VI.

Building Ashpits. After the footings have been laid it is a good idea to allow at least three days during warm weather and at least a week during cold weather before starting the construction of ashpits.

The first step is to draw the outline of the ashpit. The outside dimensions are laid out on the surface of the footing with chalk or a pencil having heavy lead. This location is then checked by the use of plumb bobs to make certain the outline places the bottom of the ashpit so that when the walls of the chimney are built up, they will be in exactly the right position in relation to headers which the carpenters have prepared at the first floor level (see Fig. 8).

Bricks are laid without mortar around the outline of the ashpit as a means of determining the number of whole bricks which can be used and how much, if any, cutting of bricks will be necessary. The bricks are then pushed aside and mortar is spread on the surface of the footing around the outlines. The same mortar mix should be used that was recommended in Chapter VI. Common bricks are used entirely for interior chimneys. Face bricks should be used for exterior chimneys wherever the chimney surface is visible from the outside. The bricks should be well bedded in the mortar, keeping them well within the outlines. The ends of the bricks should be carefully buttered to make certain the vertical joints will be good. It should be remembered that $\frac{1}{4}''$

to ⅜″ joints make stronger masonry work than do larger joints. Once the first course has been laid, mortar is spread on the top surface of the bricks and the second course started. The joints should be staggered as shown in Fig. 4 in the elevation view.

When four or five courses have been laid, the ashpit door frame should be placed in position as shown in Figs. 2 and 4. Five or six additional courses are then laid so that there is at least one course above the door frame.

Beginning at a level flush with the bottom of the ashpit door, the ashpit walls (*M, N, R,* and *P* in Fig. 5) are started. Such walls vary
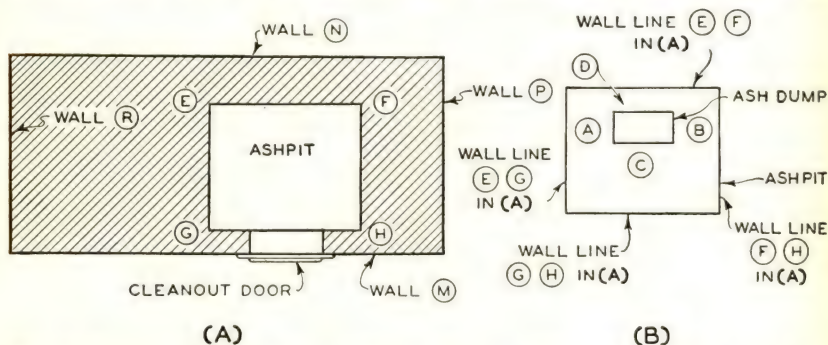
Fig. 16. Horizontal Section View of Chimney Shown in Fig. 6 Illustrating Ashpit Door (A), and Position of Ash Dump (B)

in thickness from one to three brick widths. For example, wall *M* in Fig. 5 is one brick width in thickness, or 4 inches. Fig. 16 at (A) shows a horizontal section of the chimney pictured in Figs. 4 and 5. This section was taken at the ashpit door and the walls have been marked to correspond with the same walls in Fig. 5.

The laying of the ashpit walls continues, including the placing of the cleanout door for the flue soot pocket and the furnace thimble. These two features of the ashpit wall are built in just as was described for the ashpit door. At a point 18″ to 24″ below the first-floor levels such as at *T* in the section view of Fig. 5, corbeling should be started as a means of narrowing the ashpit sides to the dimensions of the ash dumps. Fig. 16 at (B) shows the outline of the ashpit as well as the ash dump. The interior faces of walls *GE, EF, FH,* and *HG* in (A) of Fig. 16 and noted in (B) of Fig. 16 must be gradually corbeled out over the distances *A, D, B,* and *C* (see (B) of Fig. 16) until they form the ash

dump opening. This corbeling is shown at *A, D, B,* and *C* in Fig. 4. The amount each of the courses must be corbeled out and the number of courses to be corbeled must be determined on the basis of the size of the ash dumps and the wall thicknesses. Typical corbeling is visible in Fig. 6 in the section view and in the pictorial view at the cutaway part of the pictorial section just below the hearth.

Building Fireplace Floors. The parts of hearths which comprise fireplace floors (see *E* in the section view of Fig. 4) should be made of one layer of firebrick laid flat. Care should be taken to see that such floors are perfectly level and that the ash dumps are flush with them. Some-
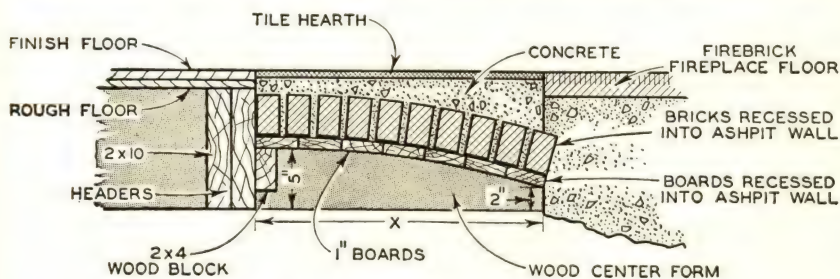
Fig. 17. Details of the Trimmer Arch

times the bricks around the dumps must be chipped in order that the dumps will be flush with the floors.

Building Trimmer Arches. Trimmer arches, shown in Figs. 4, 5, and 6, are constructed of bricks, boards, wood blocks, wood center forms, and concrete.

When ashpit walls have been built up to the level of the fireplace floors, the trimmer arches can be made. These arches extend under the hearths for the full length of the hearths.

Note the wood center form in Fig. 17. These should be spaced not more than 2′ 0″ apart under the arch. Their length, *X*, is governed by the width of the hearth. They are usually 5″ or 6″ high at the end furthest from the fireplace and about 2″ high where they are recessed into the ashpit walls. Any curvature is satisfactory as long as the concrete can be twice as thick at the ashpit walls as it is at the headers. Wood boards approximately an inch in thickness are nailed to the curved or top edges of these center forms as shown in Fig. 17. The blocking is made of 2 x 4's, 3 x 3's, etc.

When the wood center forms are in place, about half an inch of mortar of the same mix used for ashpit walls should be spread over the boards and the bricks laid, one row at a time, starting at the recess in the ashpit walls. Care should be taken to have mortar in all vertical joints. The joints should not be greater than ⅜″, and should be staggered in alternate rows.

When all bricks have been laid, stiff concrete should be placed using a 1:2:4 mix, taking care that it is carefully tamped. The top surface of the concrete should be perfectly level and half an inch or more below the surface of the finished floor surfaces, depending on what hearth surfacing is to be employed.

If bricks are used for hearth surfacing, their color, the color of the mortar, and the pattern in which the bricks are laid are worked out following the architect's designs or personal taste. If tile surfaces are required, tile setters should do that portion of the work.

The wood center forms are left in place as permanent construction.

Building Fireplaces. After the fireplace floors and trimmer arches have been completed, the jambs, end walls, fireplace side walls, and back walls are laid up. Fig. 6 shows a typical arrangement of bricks for such walls. The jambs, end walls (F and G), the fireplace side walls (E), and the vertical back wall should all be laid up at the same time, course by course. The side walls and vertical back walls are laid with firebrick. The inclined portion of the back wall is also laid course by course with the other sections so as to be supported by the side walls.

Lintels should be placed when the jambs are up to the maximum opening height, as in Fig. 3. Each end of the lintel should have a bearing of at least 3 inches. The inclined back walls are laid up to the required heights (b in Fig. 3) while at the same time continuing the laying of the rear walls back of the smoke chambers. The smoke shelves are made of mortar in such a way that they have a curved or dished surface. The size of the throat depends on the damper to be used.

Study the pictorial section of Fig. 6 and the dotted lines from ff to ee to tt in the elevation view of Fig. 3 to see how smoke chambers are formed above throats and how these chambers gradually are reduced in size and shape to form flue dimensions.

Above the smoke chamber the chimney is built as explained in Chapter VI.

Brick or stone mantels, as pictured in Figs. 6 and 10, are easily installed as shown in those illustrations. Wood mantels and any surrounding woodwork are installed by carpenters.

The building of modified fireplaces and their chimneys is exactly the same as has been explained for plain fireplaces except that the metal cases support some of the masonry work and that some of the masonry work is laid up around the casings and their various heat ducts and registers.

ESTIMATING

The method involved in estimating the number of bricks required for fireplaces and chimneys is explained here because so many inexperienced masons require a knowledge of the procedure.

The fireplace and chimney illustrated in Fig. 3 are used as an example. In Fig. 6, two sets of dimensions are given. There are those which refer to the *approximate* sizes of the voids or openings. All others refer to the outside dimensions of the masonry work. The letters A to F in the elevation indicate sections used in estimating the quantities of brick required.

A convenient method for estimating the number of bricks in fireplace chimneys is to calculate the volume of the various sections which differ in outside dimensions and then subtract the voids or hollow spaces which constitute the ashpits, fireplaces, flues, etc. This will be the total cubic feet of brickwork which, when multiplied by 22.5, is converted to the number of bricks required. For ease in making calculations, inches and fractions of an inch can be converted to feet by multiplying by 0.0833. In Fig. 5, most dimensions are in thirds of a foot or quarters of a foot. In such cases it is simpler to express the dimension in decimals. For example, 12′ 8″ (height AB in the elevation of Fig. 5) becomes 12.66 feet since 8″ equals two-thirds of a foot. In estimating the number of bricks for any fireplace and chimney it should be remembered that the answer will be a *close approximation*. For this reason it is not necessary to provide dimensions for each section of the chimney and fireplace. For example, the corbeled section BC in the elevation view has no width dimension. However, it is close enough in width to the section EF for the purposes of the problem. Therefore, this dimension is used.

1. The first step is to estimate the total volume of masonry by multiplying together the width, depth, and height of the various sections of fireplace and chimney pictured in Fig. 5.

Section	Width (Feet)		Depth (Feet)		Height (Feet)	Volume (Cubic Feet)
AB	6.0	×	2.75	×	12.66 =	208.89
BC	4.25	×	2.5	×	1.66 =	17.60
CD	3.5	×	2.0	×	2.0 =	14.00
DE	3.5	×	1.75	×	10.16 =	62.20
EF	4.33	×	2.5	×	6.0 =	65.00

Total volume   367.7

2. Next, estimate the total volume of the voids by multiplying together their width, depth, and height.

Section	Width (Feet)		Depth (Feet)		Height (Feet)	Volume (Cuic bFeet)
Ashpit	2.33	×	1.5	×	7.0 =	24.46
Fireplace	3.0	×	1.5	×	3.5 =	15.75
Smoke chamber	2.0	×	1.16	×	2.0 =	4.64
8½″ x 13″ flue	.76	sq. ft.		×	28.5 =	21.66
13″ x 13″ flue	1.17	sq. ft.		×	18.75 =	21.93
8½″ x 13″ flue	.50	sq. ft.		×	18.75 =	9.37

Total volume of voids   97.81

3. Subtract the volume of the voids from the total volume of the masonry.

$$367.7$$
$$-97.8$$

Net volume, therefore, $\overline{269.9}$

4. Multiply the net volume of masonry by the number of bricks per cubic foot.

$$269.9$$
$$\times 22.5$$
$$\overline{6,072.75}$$

The number of bricks required to lay the fireplace and chimney pictured in Fig. 5 will be 6,072, or 6.1 thousand bricks.

To estimate the mortar needed to lay the fireplace and chimney shown in Fig. 5, multiply the mortar material (which will give a 1:1:6 mix for 1,000 bricks) in the following by 6.1.

Bags, hydrated lime............ 2.6 × 6.1 = 16 bags
Sacks, Portland cement......... 3.5 × 6.1 = 22 sacks
Sand, cubic feet..............18.0 × 6.1 = 110 cubic feet

Other materials which will be needed to construct this fireplace and chimney include:

One each, 6″ and 8″ thimble   One damper
28′ of 8½″ x 13″ flue lining   Two cleanout doors
20′ of 13″ x 13″ flue lining   One ash dump
20′ of 8½″ x 8½″ flue lining   One mantel

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. Where steel or iron is used in the construction of a plain fireplace?
Answer. The lintel is made of steel and the damper is made of iron.

2. What the minimum recommended thickness is for the back wall of a fireplace chimney?
Answer. The minimum thickness is 8 inches. (See Fig. 3.)

3. Where wood centers are used in fireplace construction?
Answer. They are used in connection with the trimmer arch.

4. Where trimmers are used?
Answer. They are a part of the joist framing on either side of a fireplace. (See Fig. 8.)

5. Of what material cleanout doors are made?
Answer. Cast iron. (See Fig. 6.)

6. Why the warming effect of a plain fireplace is of little consequence?
Answer. Because such warming effect is produced by radiant heat which travels in straight lines.

7. Why it is that plain fireplaces draw cool air into a room?
Answer. Because as air enters the fireplace it becomes heated and rises up the flue. This causes a suction which draws in cool air through the cracks in the walls and around windows and doors.

8. What principle makes modified fireplaces more efficient than plain fireplaces?
Answer. The principle of the circulation of warmed air.

9. Which items comprising a fireplace are important from the standpoint of proper functioning?
Answer. The shape and relative dimensions of the combustion chamber, the proper size and location of the throat, the proper relation of the throat to the smoke chamber, and the proper flue area.

10. What purpose the damper serves?
Answer. It regulates the draft and prevents loss of heat up the flue.

11. What purpose smoke shelves serve?
Answer. They keep down drafts from blowing into the fireplace.

12. What a practical height is for a fireplace opening which is less than 6' 0" in width?
Answer. Thirty inches.

13. What depths are recommended for fireplaces?
Answer. Fireplace depths are recommended at 16" and 18 inches.

14. What should be the maximum inclination for fireplace back walls?
Answer. The maximum inclination should be 30 inches.

15. How inches and fractions of inches can be changed easily to feet, expressed in decimals?

Answer. By multiplying them by 0.0833.

16. How many sacks of cement are required for a 1:1:6 mortar mix to lay 1,000 bricks?

Answer. Three and one-half.

17. What tail beams are?

Answer. They are the joists which are supported by double trimmers around the floor openings for fireplace chimneys. See Fig. 8.

REVIEW QUESTIONS

1. Why must smoke chambers be constricted at throats?
2. How deep should throats be and what is a good width?
3. What happens when the opening of a fireplace is too high?
4. What is the principal difference between plain and modified fireplaces?
5. Why is it that plain fireplaces do not heat a room well?
6. Does a shallow fireplace throw out as much heat as a deep one?
7. What is the purpose of a smoke shelf?
8. Where should firebrick be used in a fireplace?
9. What width should jambs be and why?
10. What is the breast of a fireplace chimney?
11. Explain how to calculate the required flue area for a fireplace.
12. Does air travel in more than one direction in a fireplace flue? Why?
13. Why are the sides of a fireplace inclined?
14. What is the function of a trimmer arch?
15. Why are blank flues sometimes built into fireplace chimneys?
16. What shape should smoke chambers be?
17. What is a projecting jamb?

Walls and Partitions

QUESTIONS CHAPTER VIII WILL ANSWER FOR YOU

1. *What are the important features of walls and partitions?*
2. *What are the various kinds of walls and partitions and what are the advantages of each?*
3. *What are the important points to be remembered in the construction of walls and partitions?*
4. *How do building codes affect the erection of walls and partitions?*
5. *What is the treatment of specialized materials such as glass blocks?*

INTRODUCTION TO CHAPTER VIII

Walls have been an important part of man's existence since the dawn of history. He has used them to protect himself and his family and belongings from the elements. He has employed them in building his great religious edifices and tombs. He has depended on them for protection against his enemies. In fact, it is difficult to conceive of a time when man existed without the protection and comfort of a wall.

For the most part the development of the wall has paced the advance of civilization, reflecting man's cultural progress as he evolved from the more primitive stages to his present level of attainment. The first attempts at building what we would call a wall undoubtedly were crude. Perhaps early man merely reinforced the tangled underbrush around him in an effort to shelter himself from chilling winds and the depredations of animals. It is easy to visualize his gradual adoption of such materials as tree trunks, clay, and stone, as his knowledge and skill increased.

In any event, archaeological discoveries at Chaldea, Tello, and Nippur in what is now Iraq reveal that wall building had reached an advanced stage of perfection some 5,000 years B.C. The material used in this construction was for the most part sun-dried brick, especially in the more humble domestic buildings. Stone was used in the structures dedicated to religious functions, buildings of state, and for the tombs of the local dignitaries. It is interesting to observe that the ruling classes of these early civilizations were less concerned with improvements of general living conditions than they were with the erection of huge monuments or in the construction of great walls for the purposes of defense.

Although the modern wall serves the same functions as those built in the past, improved construction techniques and the introduction of new materials have resulted in structures which are vastly superior in every respect. The

architectural treatment of walls has been greatly influenced by these factors since the more progressive architects have been quick to take advantage of the possibilities offered. The net result to the mason is a greater demand on his skill, knowledge, and experience.

One of the more radical of these new materials is glass block. Since the introduction of this material a few years back, it has enjoyed great popularity because of its many advantages. It is an excellent insulator against heat and cold and the passage of sound. It affords natural illumination, yet retains privacy for the occupants of any building in which it is used because of the translucent character of the glass.

Another relatively recent building development requiring great skill and care during construction is the use of the panel wall and any of the several types of insulating blocks in conjunction with a brick veneer. While none of these walls is beyond the skill of the average mason, they are difficult to lay up properly and a thorough knowledge of the many details connected with their construction is imperative.

This chapter on walls and partitions is a comprehensive treatment of these points in addition to many others too numerous to mention here. Virtually every type of composite wall in general use is described. This information is presented in a logical series of steps—Planning and Construction, Theory, Kinds of Walls, Design of Walls, and Building Walls. Such systematic presentation is invaluable since a complete background in the building of walls and partitions is a definite aid in their actual construction.

PLANNING AND CONSTRUCTION

Masonry walls and partitions for residences and other small buildings must be planned by taking into consideration each and every requirement they must satisfy. Such planning constitutes the selection of the particular kinds of walls or partitions to be used and the design of them from the standpoints of materials, thicknesses, heights, bonding, mortar joints, stiffeners, anchors, and other important features, all of which must be known and thoroughly understood by the mason or architect doing the planning. Once the planning is completed, the actual construction can be started. Construction must be carried on just as carefully as the planning, following definitely prescribed building practices and workmanship standards. Both careful planning and good construction are necessary in order to make walls and partitions satisfactory in terms of safety as well as functional requirements.

This chapter explains the general theory of walls and partitions, describes the various kinds in common use, and tells how they should be designed and constructed. The purpose of these various explanations is to set forth good planning and construction procedures.

THEORY OF WALLS AND PARTITIONS

There are several general aspects of theory which should be understood in order that walls and partitions can be selected, designed, and constructed properly. Typical examples are explained in the following paragraphs.
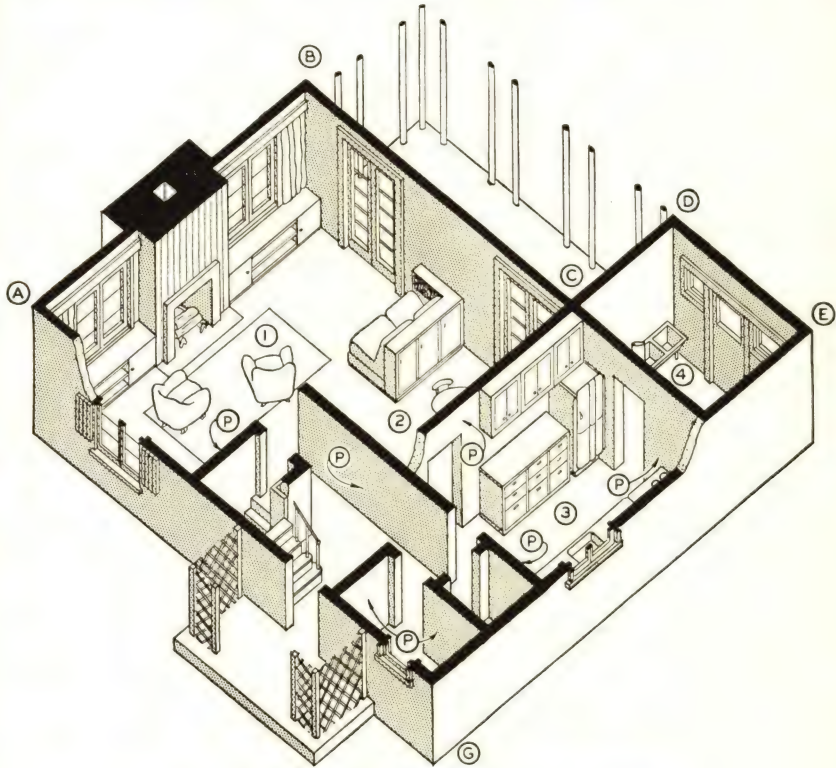
Fig. 1. Cutaway View of a Typical Small Residence

Walls. With regard to residences and other buildings, walls are thought of as the upright enclosing parts of the structure. For example, in Fig. 1, walls are shown at *AB, BC, CD, DE, EG,* and *GA.* These walls actually enclose the residence. Sometimes such walls are called *outside walls* but the term *wall* or *walls* is sufficiently descriptive and true of any type of building when used with this definition in mind.

SELF-SUPPORTING WALLS. In residences and other small buildings, masonry walls are not supported by any structural members other than the foundations. Between the foundations and the tops of roof lines of such structures, the walls are continuous or without interruption except for window or door openings. Such walls are termed self-supporting walls.

SUPPORTED WALLS. In large buildings which have a skeleton or framework of steel and/or reinforced concrete, walls are usually supported from floor to floor by the horizontal beams or spandrels. Such walls are called supported walls.
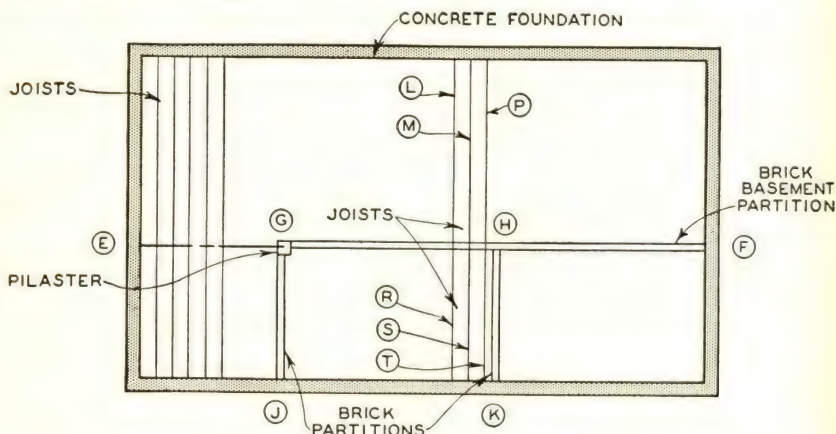
Fig. 2. Basement Plan for a Small Residence

Partitions. Partitions are the upright enclosing parts for rooms or other areas *within* a building. For example, the upright enclosing parts marked *P* in Fig. 1 are partitions. Sometimes partitions are called *inside walls* but, strictly speaking, this term is incorrect and should not be used. Other examples of partitions are shown at *GJ, HK,* and *GF* in Fig. 2.

BEARING PARTITIONS. When a partition is required to partially support joists, it is called a bearing partition. For example, note partition *GF* in Fig. 2. It can be seen that joists *L, M,* and *P* and *R, S,* and *T* are supported at one end by the partition. A portion of the floor load which the joists carry is transferred to the partition supporting them. Thus, the partition must support part of the heavy floor loads in addition to its own weight and that of the joists. Bearing partitions are

designed primarily to give them sufficient strength to support such loads safely. As these loads may be great, adequate design is essential.

Another example of bearing partitions is shown in Fig. 3 where AB and CD represent such partitions. Partition AB supports one end of the attic joists between A and E, and F and A plus part of the attic floor load. Partition CD supports one end of the joists between JB and KB, the second floor load, and the entire load supported by partition AB. This situation shows even more clearly that bearing partitions must be carefully designed to assure their being strong enough to support the loads.
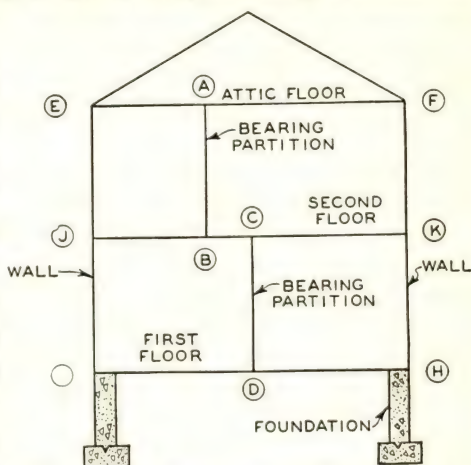
Fig. 3. Sketch Showing a Two Story Residence in Section

NONBEARING PARTITIONS. When partitions are used entirely as a means of enclosing a room or other area and do not have to support joists or floor loads, they are called nonbearing partitions. Partitions GJ and HK in Fig. 2 come under this classification. The design of this type of partition is possible with only a few simple requirements being considered.

Partitions frequently are made thicker than structural requirements demand in order to conceal plumbing pipes, heating ducts, clothes chutes, etc. However, partition thicknesses should always be in multiples of 2, such as 4″ and 6 inches. All openings, as for windows and doors, must have some form of lintel over their tops.

Parapet Walls. Apartment, store, and other such buildings usually have flat or nearly flat roofs. In such structures the walls are built up somewhat higher than the roofs as indicated in Fig. 4.

The stability of the parapet wall is of considerable importance because of the danger to life and surrounding property in the event of damage to it during wind storms or earthquakes. In most cities, building codes rigidly regulate the height of the parapet wall. Such
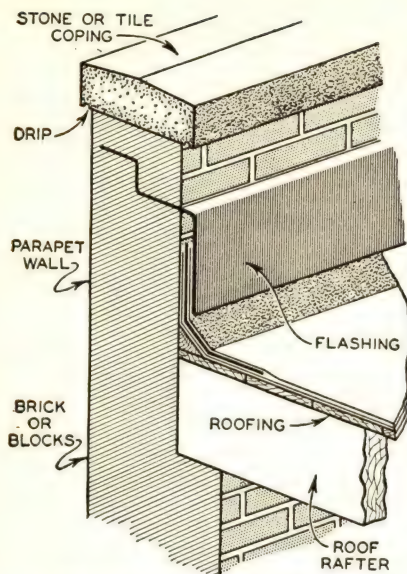
Fig. 4. Section of a Parapet Wall

regulations should be carefully fol-
lowed. In those localities where no
building code exists, it is recom-
mended that for walls 8″, 12″, 16″,
and 20″ thick, the parapet walls
should not be higher than 2′, 3′, 6′,
and 9′ respectively. These heights
have a safety factor based on wind
velocities up to 60 miles an hour.
In earthquake regions it is sug-
gested that parapet walls should
not be higher than twice their
thickness.

Note the flashing recommended
for the parapet wall as shown in
Fig. 4. Flashing is an important
means of preventing roof leaks
around the walls.

Wall Copings. Exposed walls such as parapets should be coped or
finished similar to the wall shown in Fig. 4. Such copings are made of

stone, concrete, tile, and other ma-
terials. They can generally be pur-
chased in various widths ready to
set on walls of different thick-
nesses. The basic purpose of cop-
ing is to prevent the penetration
of water into the joints of the wall.
Thus, they are a structural safe-
guard as well as a means of archi-
tectural treatment. The mortar
joints between copings and wall
tops should be carefully made.
Also, provisions should be made to
allow for expansion and contrac-
tion. If coping, as shown in Fig. 4,
is not confined by the masonry of
the walls, no expansion or contrac-
tion damage is likely.

Fig. 5. Chase in a Masonry Wall

Wall Chases. Chases are square or rectangularly shaped vertical recesses in walls which are provided to accommodate pipes, heating ducts, and similar equipment. The horizontal section of the wall shown in Fig. 5 illustrates a typical chase. In general, chases should not be deeper (dimension A in Fig. 5) than one-third the thickness of the walls they are in. Table I gives recommended chase dimensions for the more commonly encountered pipe sizes. Chases for other purposes than shown in Fig. 5 should be designed by a structural engineer since too large a chase in a wall of a given thickness would seriously weaken the wall.

TABLE I. CHASE DIMENSIONS

PIPE SIZE IN INCHES	DIMENSION A (FIG. 5) IN INCHES	DIMENSION B (FIG. 5) IN INCHES
2	4½	6
3	5½	8
4	6½	9
5	7½	10
6	8½	12

Corbeling of Brick Walls. When brickwork is corbeled out to provide support for various structural members, each succeeding course should not project more than 2″ beyond the course below. The maximum projection of corbeling beyond the face of a wall should not be more than one-half of the wall thickness. Several examples of corbeling were given in Chapter VII on the construction of fireplaces.

When other structural members are supported by wall corbeling they constitute what engineers call *eccentric loads*. If such loads are especially heavy they have a tendency to affect the stability of the wall. Such walls, therefore, should be designed by a structural engineer. If the services of such an engineer cannot readily be obtained, masons are advised to erect pilasters under such loads rather than run the risk of constructing a wall which would be unstable because of the eccentric loading placed upon it.
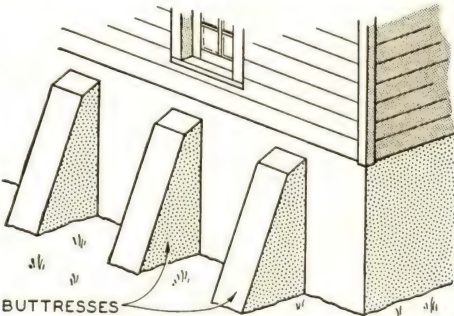
BUTTRESSES

Fig. 6. Use of Buttresses Give Long Wall Stability

Buttresses in Walls. Pilasters frequently are employed to give long

masonry walls greater stability against overturning. Pilasters used for this purpose are built on the inside of the wall. When a wall is stabilized from the outside (see Fig. 6), the device is called a buttress. The advantage of the buttress is that the inside face of the wall it stabilizes is free of the projection which would be present had the pilaster been used. The design of buttresses including their size and spacing depends on graphical analyses which should be done by a structural engineer. Proper buttress design will insure a stable wall.
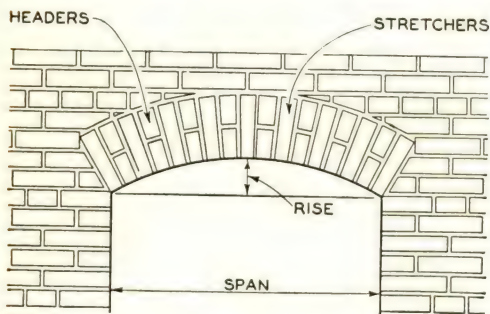
Fig. 7. Typical Segmental Arch in a Brick Wall

Arches in Brick Walls. In most cases, arches in brick walls are supported by some form of lintel. However, segmental arches of the kind shown in Fig. 7 can be constructed so as to be safely self-supporting. Note the rise which is indicated in Fig. 7. The rise for such arches should be equal to 1″ for every foot of span. For example, if the span is 4′ 0″, the rise should be at least 4 inches. Note that standard bricks can be used with alternate headers and stretchers.

Openings in Unit Masonry Walls. Openings, such as for doors and windows, in walls built of individual masonry parts (units), should be located so as to avoid, as far as is possible, the cutting of any of the units in order to make them fit. For example, suppose a brick wall were to be constructed using standard bricks with ⅜″ mortar joints. A window or door opening in this wall should be located so that whole bricks can be laid between the side of the window or door opening and the nearest corner of the wall. This subject is discussed further in the design portion of the chapter.

Fire Resistance of Brick Walls and Partitions. Walls and partitions constructed of brick are perhaps more fire resistant than most other kinds of walls. The resistance of various thicknesses is described in the U.S. Bureau of Standards *Letter Circular No. 228*. This letter should be obtained and studied when fire-resistive walls or partitions are to be designed and constructed.

Clay Products Masonry. Walls or partitions constructed of units which are made from clay products such as brick and tile are classified as clay products masonry.

Concrete Masonry. The term concrete masonry is applied to all kinds of blocks, bricks, and tile units molded from concrete.

Crack Prevention in Masonry Walls and Partitions. There are many precautions which can be taken to prevent cracks when walls and partitions are being designed and constructed. Some of the more important of these are briefly explained in the following paragraphs.

FOOTINGS. One of the principal causes of cracks is uneven settlement of footings. Soft places under footings or vibration from trains, streetcars, or heavy traffic causes uneven settlement with the result that, regardless of the masonry material used, cracks soon develop. The best precaution in regard to footings is to make them of sufficient dimensions and deep enough in the soil to insure their having solid bearing.

BONDING AND TYING. Where masonry is used as veneer in a frame building and when masonry partitions are used in the same type of structure, the masonry should be securely anchored to the structural members of the building. Where one masonry wall joins another, the two walls should be securely united at the intersection with a masonry bond or metal ties. This also applies to partitions.

TEMPERATURE CHANGE. A variation in temperature of 100° will cause a linear change of ⅝″ in a masonry wall which is 100′ in length. This change in length sets up stresses in the wall which are likely to cause cracking, especially around openings or where walls abut, unless adequate provisions are made for proper bonding in the walls.

OPENINGS. Stresses set up in walls and bearing partitions due to uneven settlement, temperature change, or concentrated loads, are more apt to produce cracks at door and window openings than anywhere else. Proper lintels spanning such openings will prevent such cracking.

CONCENTRATED LOADS. When beams, for example, transfer heavy loads to walls, cracking may take place. This can be avoided through the use of pilasters under such loads.

WORKMANSHIP. Good workmanship goes a long way toward avoiding cracks in walls and partitions. If the mason is not careful to make certain of an even and sufficient bedding for each course, cracking is almost sure to occur.

MORTAR. There is no substitute for good mortar. If mortar is made of the proper materials and they are of good quality, and if the ingredients are correctly mixed, a great cause of cracking will have been avoided. Poor sand, insufficient lime, insufficient cement, and improper mixing are sure to cause wall and partition defects which may easily become serious.

SHRINKAGE. All masonry units, whether made of clay or concrete, shrink between the time they are first formed and when they are ready for use. Therefore, care should be taken to use only those masonry units which have been properly cured or dried. Use of green units will cause cracking in walls and partitions as the units shrink.

Facts about Watertight Walls. When masonry walls leak during rain storms, the fault is not in the masonry units used in the construction of the walls but in the joints between the units, because of poor workmanship, or because of insufficient flashing.

JOINTS. The first requirement in the prevention of leaky joints is the use of a proper mortar. The mortar must be strong while, at the same time, possessing good bonding quality. By bonding is meant the tendency of the mortar to stick tightly to the masonry units. Generally speaking, mortar having some lime content will stick well enough to avoid moisture leaks. Joints finished by simply passing the edge of a trowel over them tend to increase the chances for the development of leaks. In making these joints there is a tendency to open the body of the mortar and draw it away from the masonry unit, forming small ledges upon which water can collect. On the other hand, carefully made concave and **V** joints (see Fig. 38) afford excellent protection against leaks and are highly recommended. These joints have excellent surfaces for shedding water and their formation requires pressure sufficient to compress the mortar and create a firm bond between the mortar and the units of masonry.

Bed joints must be full and level and not deeply furrowed. Mortar should be carefully applied to all joints so that they are tightly filled. Tool finishing of joints should be delayed until the mortar has stiffened sufficiently to hold its shape.

In all cases, thin joints are best because it has been proven that such joints produce a stronger, more watertight wall.

FLASHING. Flashing should be placed under all vertical joints in

sills, coping, caps, or other horizontal surfaces which may permit the accumulation of water or the passage of water through them. For an example of flashing, refer to Fig. 4.

Factors Affecting Masonry Walls and Partitions. The factors which govern the strength of masonry walls and partitions have been determined through years of scientific study and research. Some of the principal factors are briefly set forth in the following paragraphs.

STRENGTHS OF UNITS. Some clay and concrete brick, concrete blocks, clay tile, and other similar masonry units are stronger than others because of their compressive strengths, design, and size. These items should be considered when designing a wall or partition.

DESIGN OF UNITS. The design of a unit determines the area that is available for mortar bedding. Thus, a solid unit will allow full mortar bedding while a unit having cells or cores and webs will allow considerably less bedding. The area of the cells or cores and webs cannot be considered in terms of bedding. Mortar
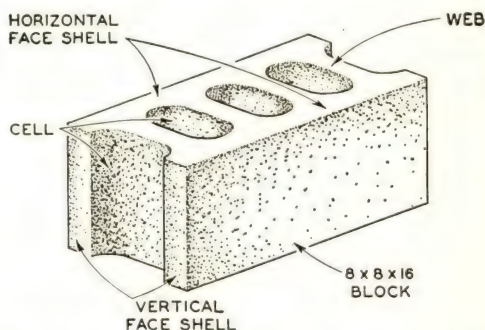
Fig. 8. Concrete Masonry Unit Showing Face Shells and Webs

is applied only to horizontal and vertical face shells (see Fig. 8) when walls and partitions are constructed of such units. Hence, units allowing full mortar bedding produce stronger walls and partitions.

REGULARITY OF UNITS. Units that are true in size and shape produce much stronger walls and partitions than poorly or irregularly shaped units.

SIZE OF UNITS. The size of the unit used in a wall or partition governs the number of mortar joints. The more joints there are, the greater the chances for variations in workmanship. For this reason, special care must be exercised in workmanship when small units are being used.

STRENGTHS OF MORTAR. To develop maximum strength in walls and partitions, regardless of the kind of units used, the mortar in the joints should be at least as strong as the units it binds together. No difficulties should be encountered from insufficient mortar strength if the proper

mortar is selected for the specific conditions of exposure and load.

Wall or partition construction with face-shell bedding requires a stronger mortar than full bedding since there is less mortar area to carry the load. A 1:1:4 mortar is sufficiently strong under general conditions. When full bedding is possible, a 1:1:6 mortar is usually strong enough.

MORTAR BOND. A strong bond is necessary between the units and the mortar to resist possible failures from such causes as vibration,

Fig. 9. Residence Constructed of Face Bricks

violent wind storms, and earthquakes. As previously explained, mortar which includes lime tends to assure good bond. A recommended mortar mix is one part Portland cement, one part lime, and six parts sand.

WORKMANSHIP. Workmanship is important from the standpoint of strength as well as for other reasons which have been discussed. No wall or partition can be depended upon if the workmanship is of poor quality.

KINDS OF WALLS AND PARTITIONS

There are many kinds of masonry walls and partitions in use for various small buildings. Some kinds are well known and are in common use, whereas others are employed under special conditions. In the fol-

lowing descriptions, only those walls and partitions in common use are discussed.

Solid Brick Walls. Solid brick walls may be constructed of clay or concrete bricks, either of which give pleasing and strong walls. Clay bricks may be obtained in many surface textures and colors. Concrete bricks can be used plain or may be painted any desired color. Fig. 9 shows a residence with typical clay brick walls.
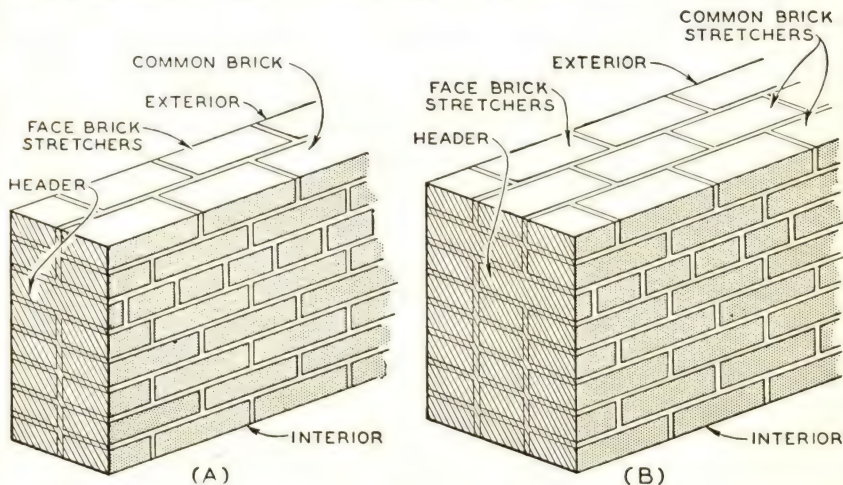
Fig. 10. Eight- and Twelve-Inch Brick Walls in Common Bond

Depending upon building code requirements or strengths desired for walls, solid brick walls are made in thicknesses of 4″, 8″, 12″, 16″, etc., all of which are multiples of four inches. Fig. 10 illustrates an 8″ wall at (A) and a 12″ wall at (B).

The word *bond* in the structural sense means to bind and, therefore, refers to the method of arranging the brick units in a wall so that, by their overlapping, the entire mass of masonry is tied together. This structural pattern results in the formation of a design on the exposed face of the masonry which is also called a bond. Bond, in addition, refers to the adhesion of mortar to the masonry units. Bond patterns in most common use are shown in Fig. 11. Note that the common bond was used in the walls shown in Fig. 10.

Fig. 12 shows section views of the head, jamb, and sill of a window in an 8″ brick wall as well as a section view of the entire wall from foot-

ing to roof. Common bond is the pattern which has been used in these sections. Note that the top plate is anchored by ½″ round anchor bolts 10″ long and spaced 8′ 0″ apart. Notice that joist ends must be beveled where they have their bearing in the wall. The window head section shows that a segmental arch is employed which is similar to that shown in Fig. 7. Such an arch supports only the exterior course of the brick wall. A wood lintel is necessary to support the interior courses. The

COMMON

FLEMISH

ENGLISH

ENGLISH CROSS OR DUTCH
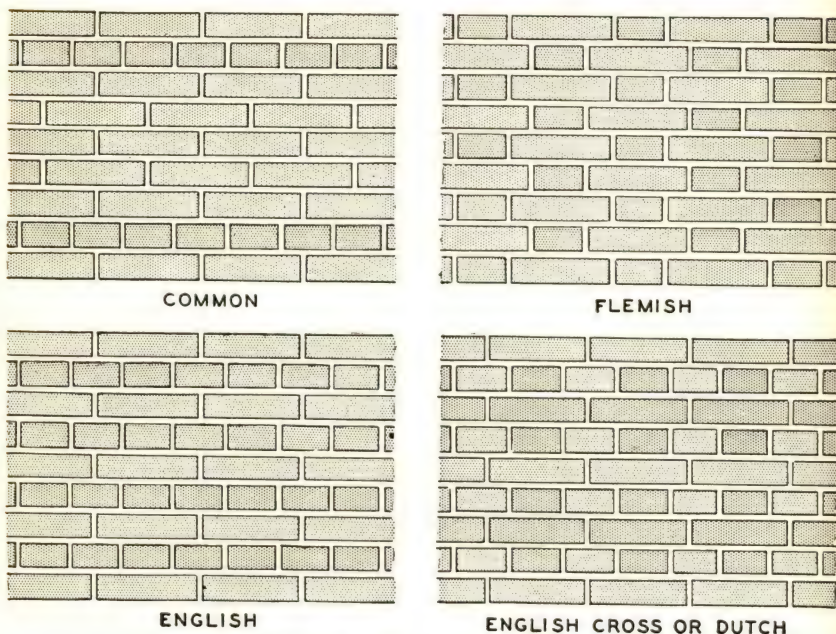
Fig. 11 Standard Bond Patterns for Brick Walls

jamb and sill sections show common construction practice, including brick sills as pictured in Fig. 9.

Solid brick walls are used in residences, store and apartment buildings, industrial structures, barns and other farm buildings, and for practically all other purposes where solid walls are desired. Either clay or concrete bricks may be used to advantage.

Brick Partitions. As previously explained, such partitions may be of the bearing or nonbearing type. Their thickness depends upon their type and the requirements expected of them. As for walls, either clay or concrete bricks can be employed in building these partitions.
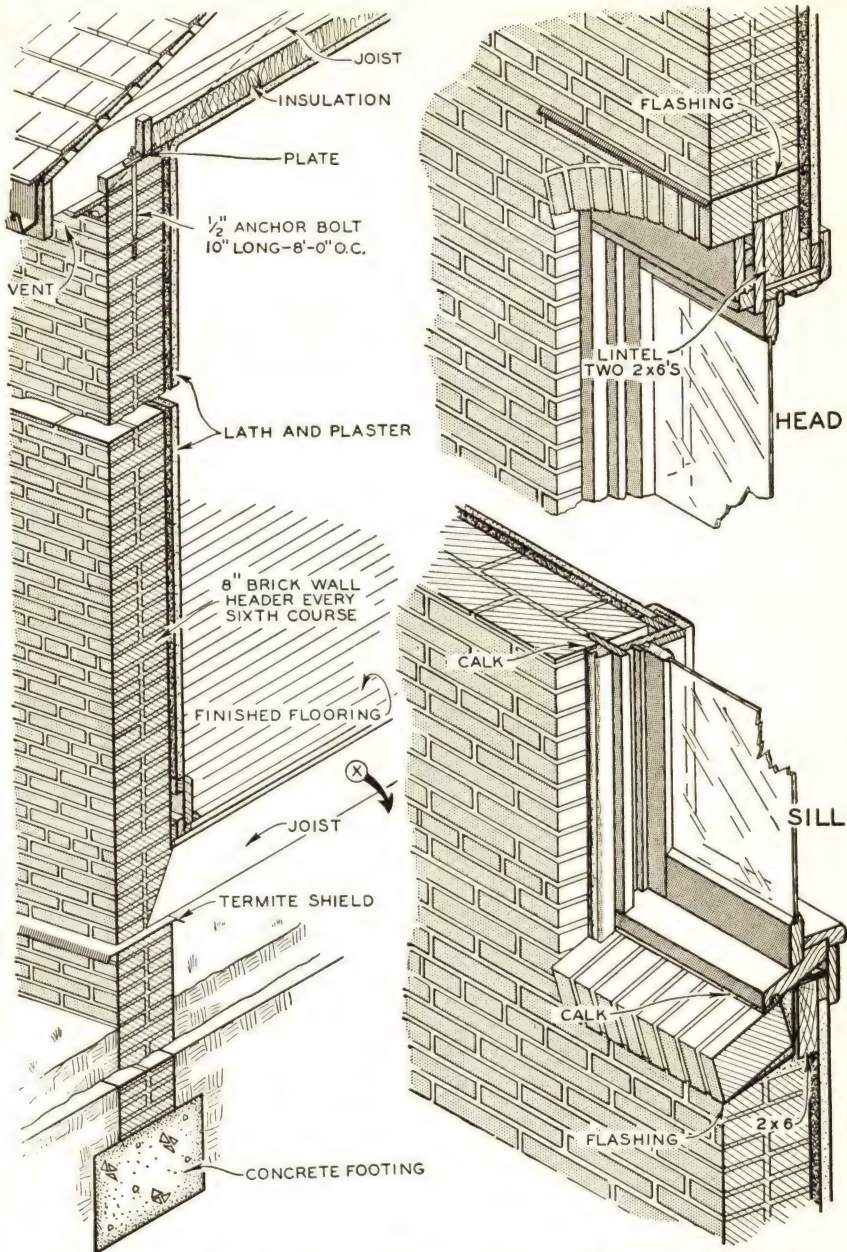
Fig. 12. Section View and Window Details for a Typical Eight-Inch Brick Wall

Fig. 13 shows the commonly used 4″ partition at (A) and a 2¼″ partition at (B). The 4″ partition is frequently employed as a bearing partition. When properly constructed, using a strong mortar and thin joints, a brick partition of this thickness can safely support heavy loads, especially if pilasters are incorporated into the partition at intervals of not more than ten feet. Some building codes prohibit the use of brick bearing partitions which are less than 8″ in thickness. However, such a

(A) (B)
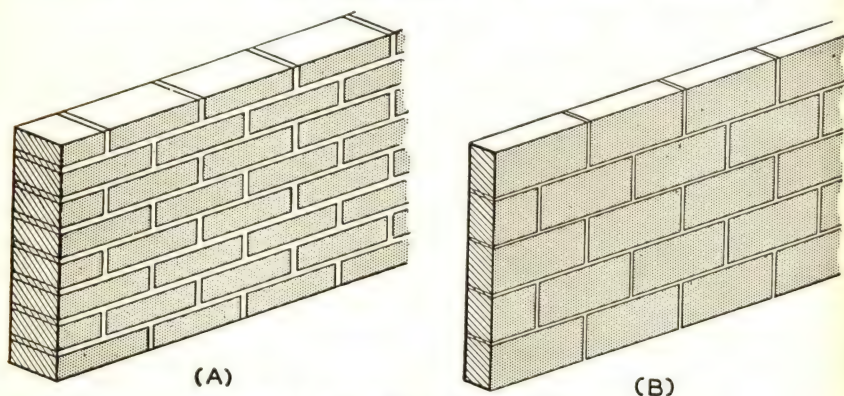
Fig. 13. Two Types of Brick Partitions

restriction is not always justified. The 2¼″ partition should never be used to carry more weight than its own.

The bond recommended for solid brick partitions is illustrated in (A) of Fig. 13. It is known as the *stretcher* bond.

Brick partitions of from 4″ to 8″ in thickness are frequently used to enclose basement spaces as well as to support floor joists. Such partitions are shown in Fig. 2. The pilaster or column at *G* and the intersecting partition at *H* impart ample stability to the long partition *GF*. Such partitions may be used for any enclosure providing footings or other ample support is supplied. They should never be used above the basement in a wood-frame building.

The 2¼″ partitions are frequently used to enclose closets, rooms, etc., where they need support no weight but their own and where they will not be subject to side forces as are the partitions surrounding a coal storage space or a granary. When such a partition is plastered with ½″ old-fashioned lime plaster on both sides, the carrying of sound through the partition is practically eliminated.

Openings in brick partitions, such as for doors, must have lintels over them. For bearing partitions, steel lintels are recommended. For non-bearing partitions, 2 x 4, 4 x 4, etc., wood lintels may be used safely.

Pier and Panel Walls. This kind of wall was developed as a means of saving appreciable amounts of material and labor. For this reason, it is known as an economy wall. A portion of this kind of wall is shown
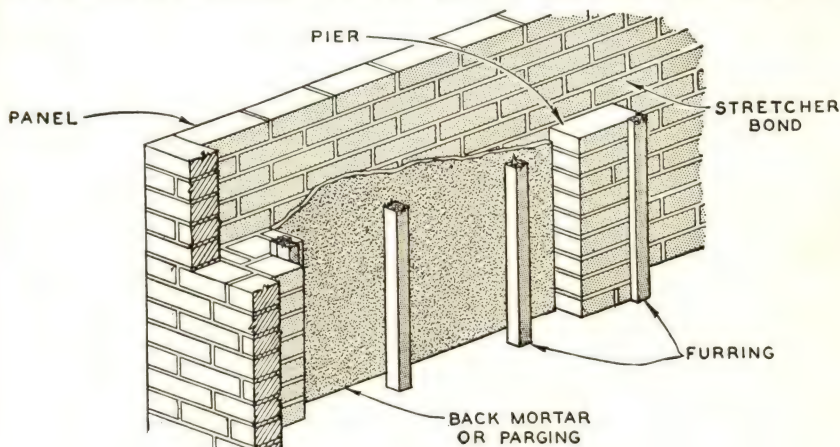
Fig. 14. Pier and Panel Brick Wall

in Fig. 14. Note the panel and piers. The panels are 4″ thick while the piers are at least 8″ square. The piers are made integral parts of the panel. Fig. 15 shows a typical wall section and pictorial views of suggested details. Fig. 16 illustrates recommended window details. Either clay or concrete bricks may be used in common stretcher bond. On the exterior, these walls have the appearance of solid brick construction.

The use of pier and panel walls is generally limited to one story residences and other small, one story structures. Such walls also can be used as garden or boundary walls. In some instances, particularly in the case of two story structures, local building codes may prohibit the use of this kind of wall.

Rolok-Bak and All-Rolok Walls. Fig. 17 illustrates 8″ and 12″ rolok-bak and all-rolok walls. The rolok-bak wall is a general utility wall. The exterior wythe, or 4″ thickness, is laid with the bricks flat and thus has the appearance of a solid brick wall. The backing wythes are laid with the brick on edge and a bond between the two is obtained by

FIRE STOP

CONTINUOUS
BOX LINTEL ANCHORED
TO EVERY PIER

4" BRICK

½" BACK MORTAR

SEE FIG. 16 FOR
WINDOW DETAILS

2 x 2 FURRING
STRIP

PLASTER

WOOD
PLATE

GRADE

SECTION

PLASTER

FURRING

PIER

PICTORIAL VIEW
OF CORNER PANEL

BACK MORTAR

WINDOW
OPENING

FURRING

FRAMING FOR
OPENINGS
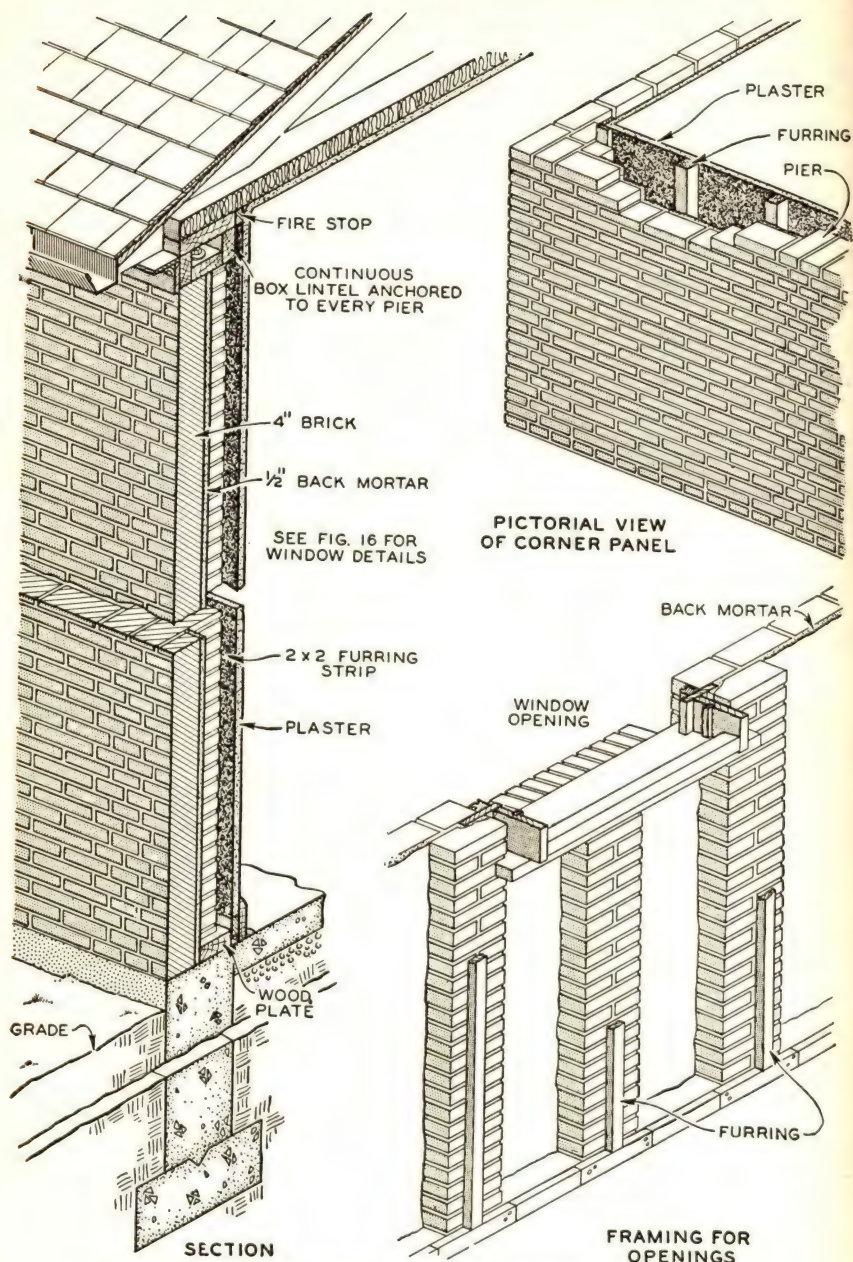
Fig. 15. Pictorial View of Pier and Panel Wall with Typical Details
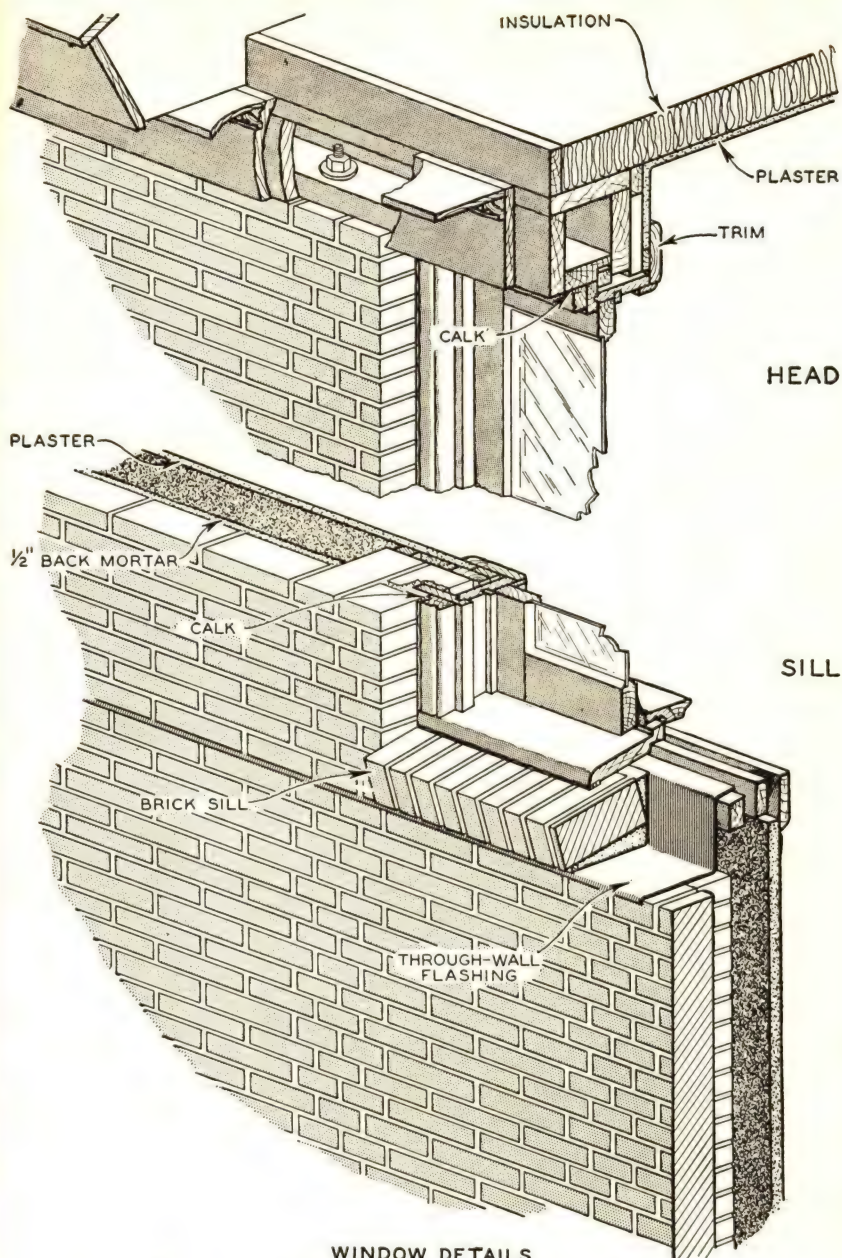
WINDOW DETAILS

Fig. 16. Window Details for a One Story Pier and Panel Wall

HEADERS

INTERIOR

2" AIR
SPACE

EXTERIOR
FULL HEADER EVERY
SEVENTH COURSE

8-INCH ROLOK-BAK WALL

INTERIOR

4" AIR
SPACE

EXTERIOR

8-INCH ALL-ROLOK WALL

INTERIOR

EXTERIOR
BASKET-WEAVE PATTERN
EVERY SEVENTH COURSE

12-INCH ROLOK-BAK WALL

INTERIOR

EXTERIOR
CONTINUOUS FLAT HEADER
EVERY THIRD COURSE
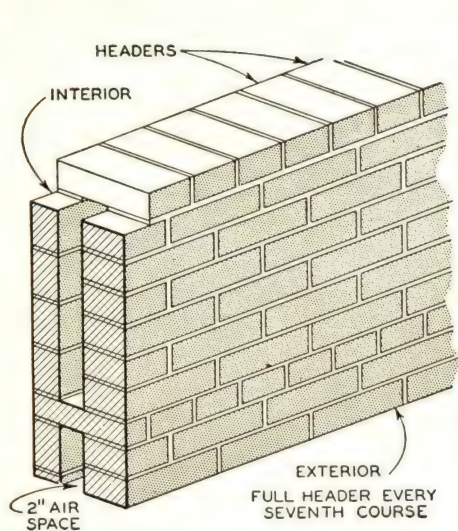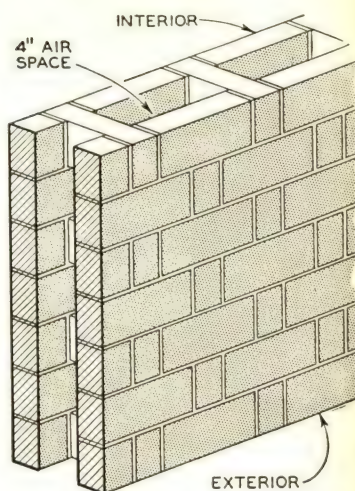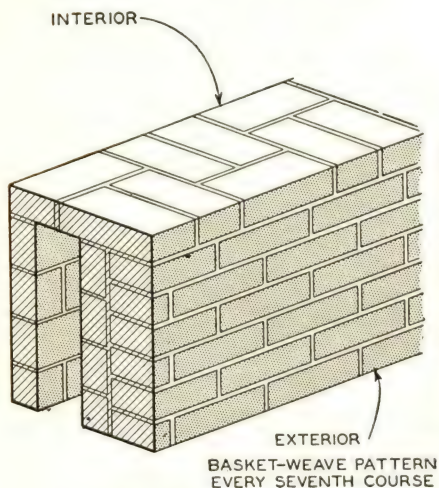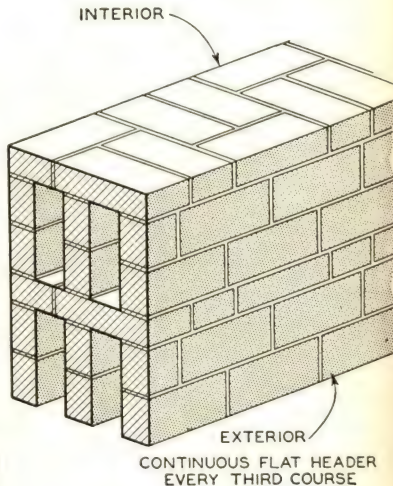
12-INCH ALL-ROLOK WALL

Fig. 17. Eight- and Twelve-Inch Rolok-Bak and All-Rolok Walls
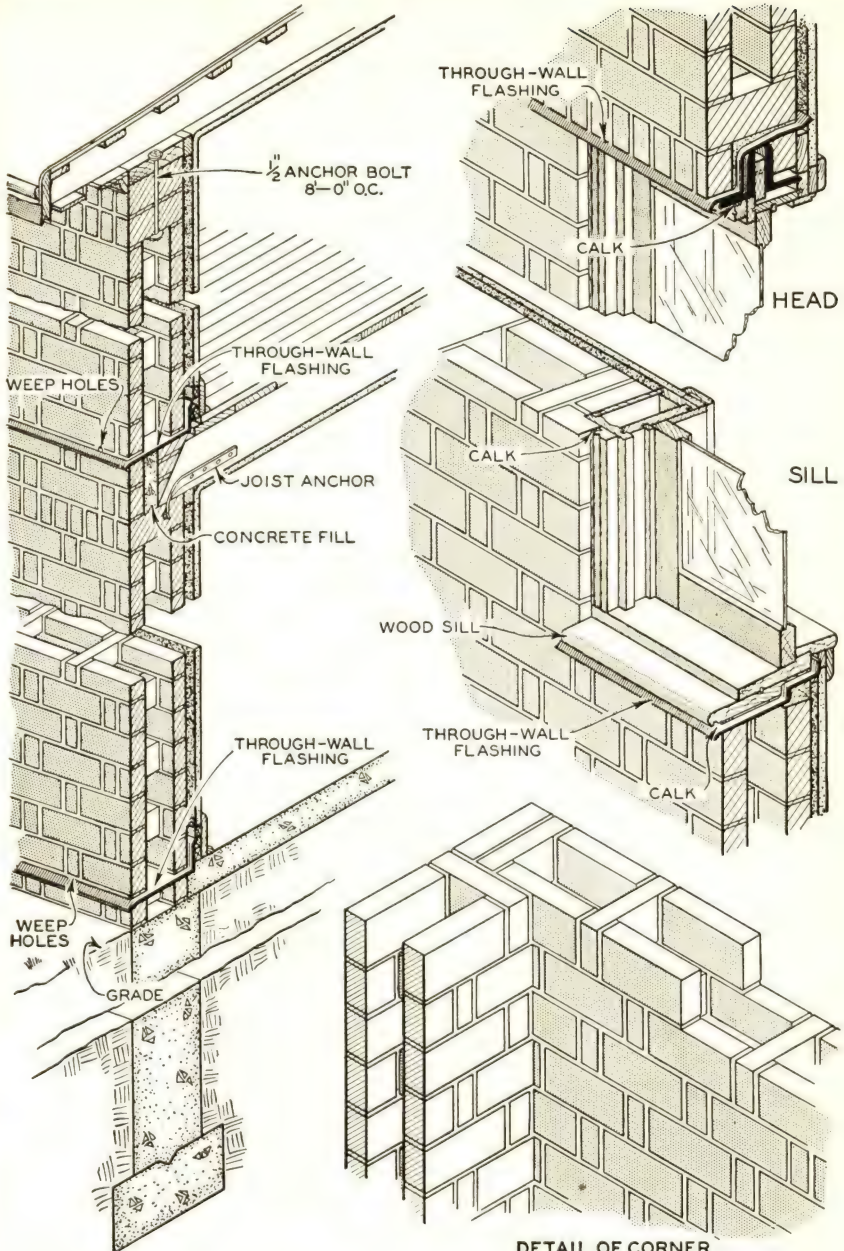
Fig. 18. Pictorial View and Details of Eight-Inch All-Rolok Wall

means of a header course at regular intervals. In all-rolok walls both exterior and interior wythes are laid with bricks on edge with headers two courses apart. The exact difference between 8″ and 12″ rolok-bak and all-rolok walls can easily be seen in Fig. 17. Fig. 18 shows a section and details of a typical 8″ all-rolok brick wall.

Either clay or concrete bricks may be used to advantage in such walls. They are never constructed more than 12″ thick. They may be used for residences, small store buildings, and for various farm structures.

Cavity Walls. Cavity walls are intended to produce a watertight wall which can be plastered direct without the use of furring strips. These walls also tend to enhance thermal and sound insulation. From the exterior they have all the appearances of solid brick walls.

The 2″ cavity between the wythes has the prime purpose of providing a barrier against the passage of moisture and heat or cold to the inner surface of the wall. Cavity walls also can be used to advantage when it is desired that the inside wythe be composed of glazed brick as for laundries, recreation rooms, dairy buildings, etc.

Fig. 19 shows a typical portion of a cavity brick wall. The stretcher type bond is always used. Note that no headers are required since metal ties are employed. Fig. 20 shows a section and other details of such a wall. Cavity walls can be used wherever an 8″ solid brick wall is used with the assurance that it will be of at least equal strength.
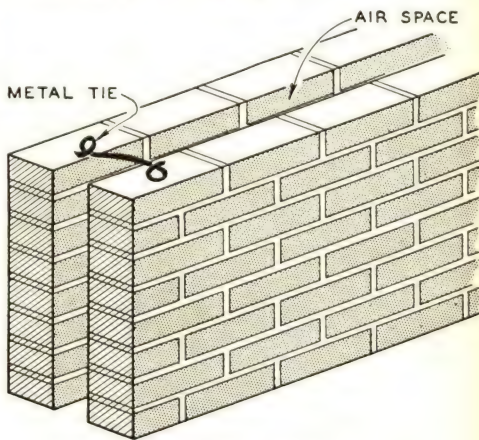
Fig. 19. Cavity Brick Wall

Tile Walls. Tile walls are made of variously shaped units having one or many cells, single or double shells, divided mortar joints, flat or irregular beds, and of various dimensions. The tile may be glazed or natural, rectangular or square, and straight or curved. Any lumberyard or dealer in building materials can supply explanatory literature about tile.

Labels in figure:

RAFTER

JOIST

$\frac{1}{2}$" ANCHOR BOLTS 14" LONG 8'-0" O.C.

PLATE ANCHOR

SECOND FLOOR

2" AIR SPACE

STEEL TIES 24" O.C. EACH SIXTH COURSE

FIRST FLOOR

JOIST ANCHOR

THROUGH-WALL FLASHING

THROUGH-WALL FLASHING

STEEL ANGLES

HEAD

CALK

SILL

BRICK SILL

THROUGH-WALL FLASHING

STEEL TIES 24" O.C. EACH SIXTH COURSE
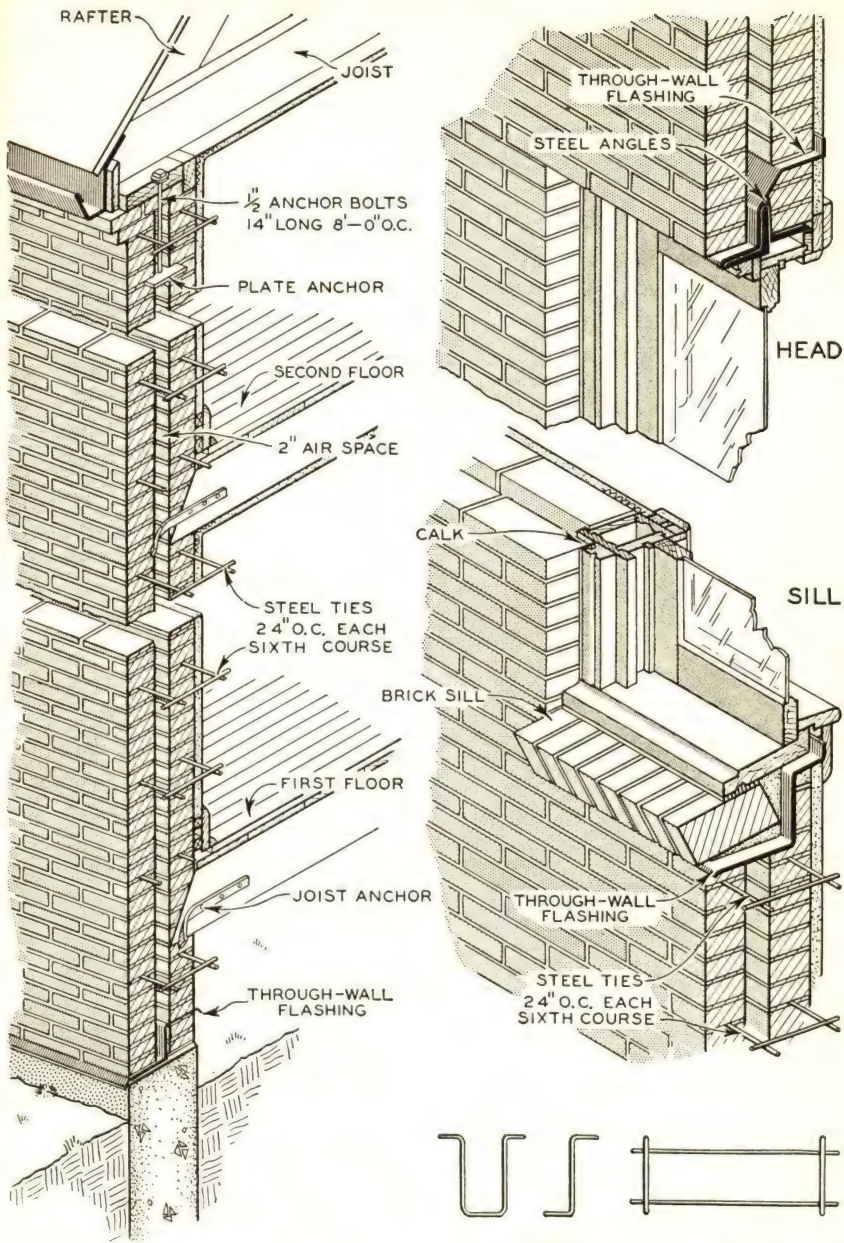
VARIOUS TYPES OF TIES

Fig. 20. Pictorial View and Details of Ten-Inch Cavity Brick Wall

EXPOSED WALLBOARD
OR PLASTER
ON PLASTERBOARD

FURRING
STRIPS

STRUCTURAL
CLAY TILE
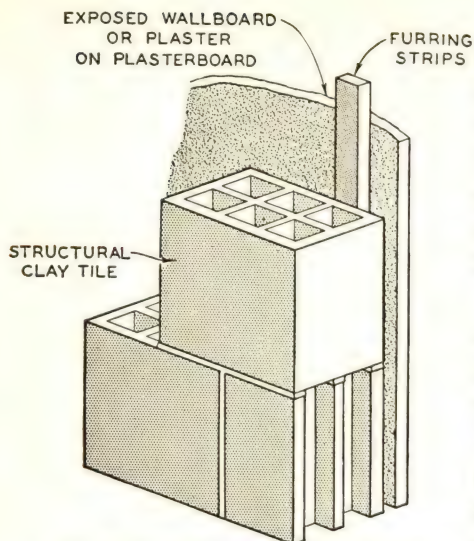
Fig. 21. Six-Celled Clay Tile Unit Used in
Building Eight-Inch Walls

Fig. 21 shows part of a wall made of six-cell tile units. Fig. 23 shows a wall section and details using the same unit. Note that window sills make use of a special multicelled unit. Note, too, the reinforced lintels.

Tile walls can be used for residences, barns, silos, milkhouses, poultry houses, and various other kinds of masonry structures. Such walls are strong and possess a great many desirable features, including quick erection, barriers to moisture and heat and cold, and great durability and stability.   Fig. 22 illustrates a tile barn and silo.

The walls shown in Fig. 24 are additional examples of tile construction. The wall in (A) is one of several kinds which can be employed

Fig. 22. Barn and Silo Constructed of Clay Tile
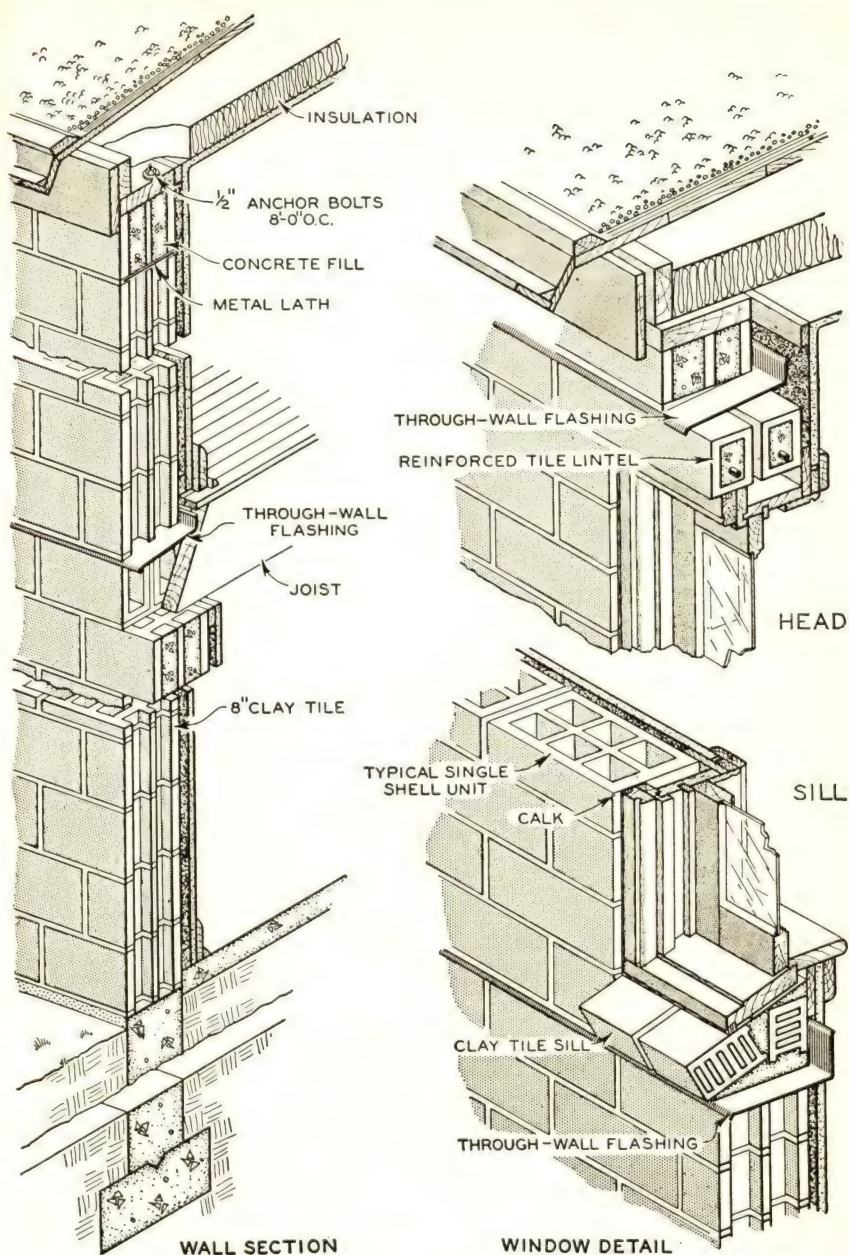
Fig. 23. Pictorial View and Details of Tile Wall Built of Units Shown in Fig. 21
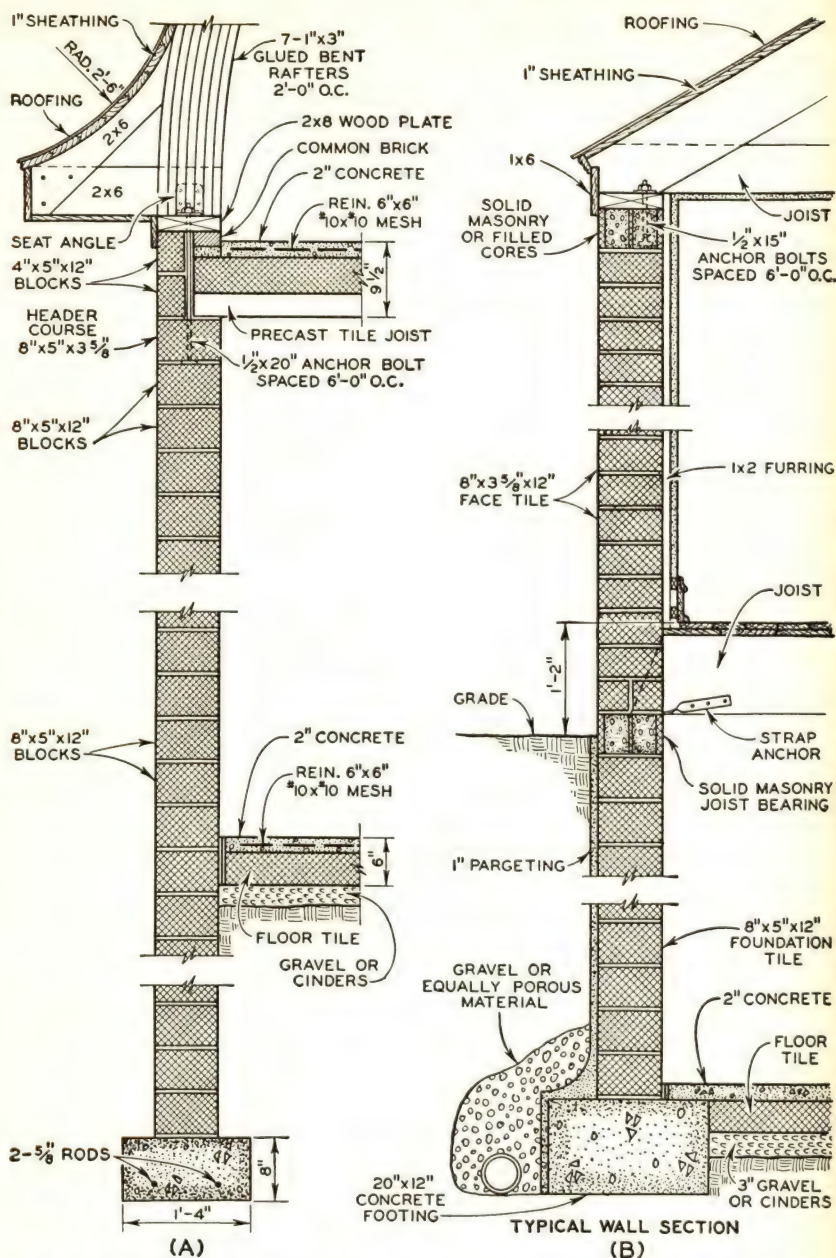
Fig. 24. Section Views of Barn Wall (A) and Residence Wall (B) Constructed of Clay Tile

for barns such as the one shown in Fig. 22. The wall shown in (B) is frequently used for residences.

Tile Partitions. Tile partitions are greatly similar to tile walls except that they are generally only 2½″ to 6″ thick, depending upon whether or not they must support loads in addition to their own weight. An example of such a load is plumbing fixtures. Units such as those previously illustrated are commonly used. They can be plastered on directly and make excellent partitions.

Units such as those shown in Fig. 25 are also frequently used for partitions when they can be supported by steel or concrete

JACK ARCH FOR OPENINGS OVER 22 INCHES

GROUNDS

Fig. 25. Partition Built of Lightweight Hollow Gypsum Units

beams or concrete floors. These units can be obtained in various thicknesses and sizes, both solid and hollow.

Tile partitions can be used in any building where they will be supported by steel and concrete beams or concrete floors. These partitions should not be used where support depends on wood framing or floors.

Brick and Tile Walls. Various combinations of both clay and concrete brick, and tile are often used in the construction of walls for residences and other buildings. Such walls have advantages in that they are generally more quickly erected than solid brick walls and the cells in the tile tend to prevent the passage of moisture, heat, and cold.

Fig. 26 shows one common manner of using brick and tile in an 8″ wall. This wall has the exterior appearance of a solid brick wall and is strong. Note that brick headers are used every fifth course of exterior brick. These headers serve to bind the wall together.

Fig. 27 illustrates the use of differently shaped tile units in a 12″

brick and tile wall. Note the typical tile units indicated as X and Y and how they are set into the wall. The Y unit provides space for a brick header every sixth course of exterior brick. In a wall of this kind the plaster can be applied directly to the tile without furring being necessary since none of the exterior bricks extend to the inside surface of the wall. Dampproofing in the form of one heavy coat of asphaltum is recommended as shown in Fig. 27.

EXPOSED WALLBOARD
OR PLASTER
ON PLASTERBOARD

FURRING STRIPS

STRUCTURAL CLAY TILE (BACKUP)

BRICK HEADER

FACING BRICK

$1\frac{1}{2}$"

8"

Fig. 26. Eight-Inch Brick and Tile Wall

Glass Blocks in Walls and Partitions. Glass blocks can be employed in walls and partitions to good advantage because they provide excellent architectural effects, because they transmit daylight through what constitutes an insulated wall or partition, because they tend to insulate against the passage of sound, because they provide daylight with privacy, and because of many other desirable features, information on which may be obtained from manufacturers' literature or building materials salesrooms.

Glass blocks can be purchased in a number of sizes and thicknesses. Standard units are $5\frac{3}{4}$", $7\frac{3}{4}$", and $11\frac{3}{4}$" square by $3\frac{7}{8}$" thick. Most manufacturers also make corner or curved blocks for use at corners and where curved surfaces are required. Many patterns (that is, the design of the block surface) are available which can be placed in two general classifications: decorative and general purpose. The blocks in the former classification are employed for exteriors or interiors of stores, residences, and other buildings where they must become a part of the architectural treatment. The general purpose glass blocks are used in industrial buildings where architectural effect is not the prime consideration. Fig. 28 shows the use of glass blocks in the walls of such a building.

Glass blocks cannot be used where they must support other than
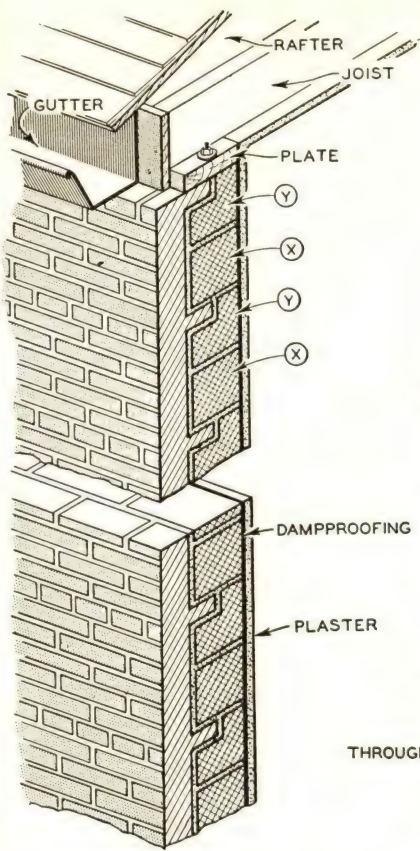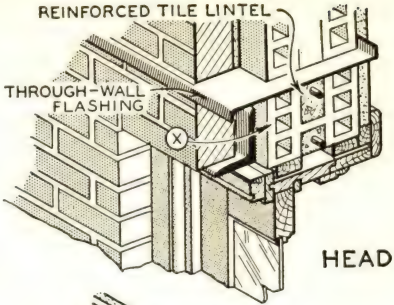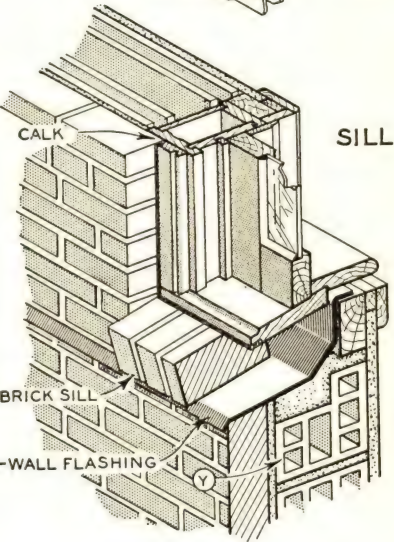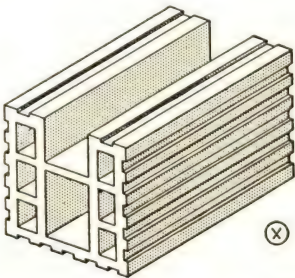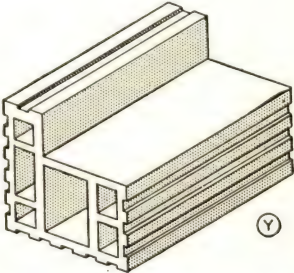
Fig. 27. Pictorial View and Window Details of Twelve-Inch Brick and Tile Wall

Fig. 28. Use of Glass Blocks in Walls of an Industrial Building
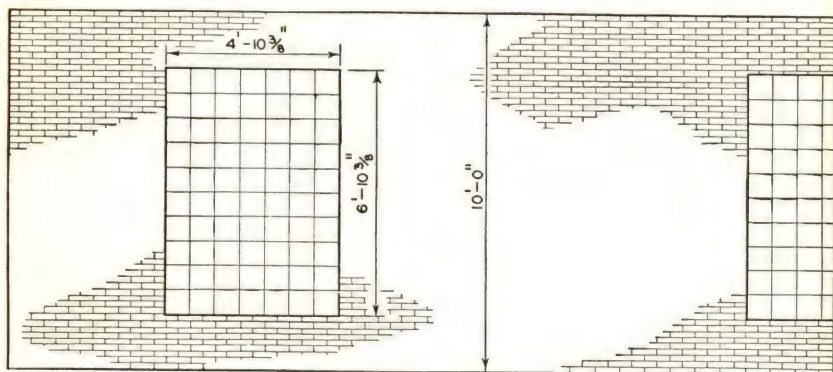
(A)
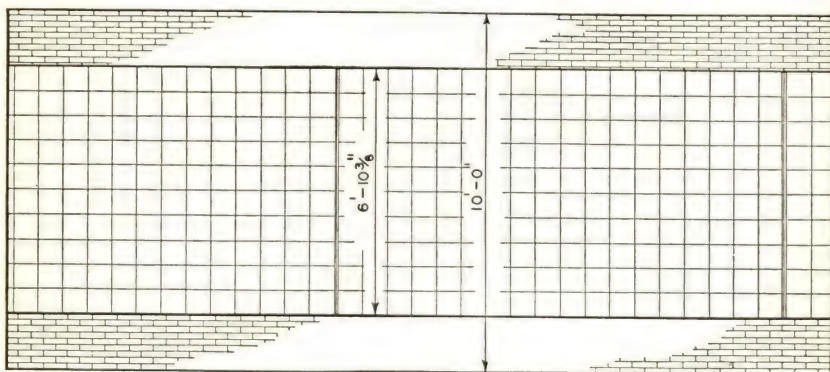
(B)

Fig. 29. Two Methods of Using Glass Blocks in Walls

their own weight. In other words, such blocks are used for small panels as shown in (A) of Fig. 29 or in long panels as in (B) and as illustrated in Fig. 28. In every case where glass block panels are to be constructed, the walls or partitions above them must be supported by lintels.

Fig. 30 shows a pictorial section view of typical glass block construction in a masonry wall. Note that steel lintel angles and a plate are used as a means of supporting the wall above the panel. Note too that there is a chase in the wall for the jamb of the panel to fit into. Chases are not always necessary but they are usually recommended as they assure a good, watertight and airtight joint. Fig. 31 shows the details of a glass block panel in a masonry partition. Note the steel lintel angles over the panel.

Glass block panels can be used in a great many ways in new buildings, and as a means of modernizing existing buildings. For new buildings, panels of various sizes can be substituted for windows as was demonstrated in Figs. 28 and 29. Or, panel walls may be designed somewhat similar to the panels shown in Fig. 15. In such cases the piers must be strong enough to support all loads above the panels. Interior partitions in residences or industrial buildings also can be constructed of glass blocks if such partitions are nonbearing or have piers at intervals to help support loads. When existing buildings are modernized, glass block panels can replace windows or be added in walls to increase natural light for interiors.

Concrete Block Walls and Partitions. Strong, economical walls and partitions can be built using concrete blocks which are manufactured in a wide variety of sizes and shapes. Many combinations of concrete blocks with tile, brick, and other masonry structural units are possible. These blocks have great utility and their possibilities should not be overlooked when planning masonry structures.

Brick Veneer Walls. The use of one wythe of brick as a veneer on frame or masonry walls is a means of obtaining the appearance of a solid brick wall plus certain other advantages such as economy in construction and better insulation qualities against the passage through the walls of moisture, and heat and cold.

The difference between brick veneer walls and solid walls can be seen in Fig. 32. It should be noted that the brick is simply an addition to the regular structure of the wood frame house. The bricks must be tied
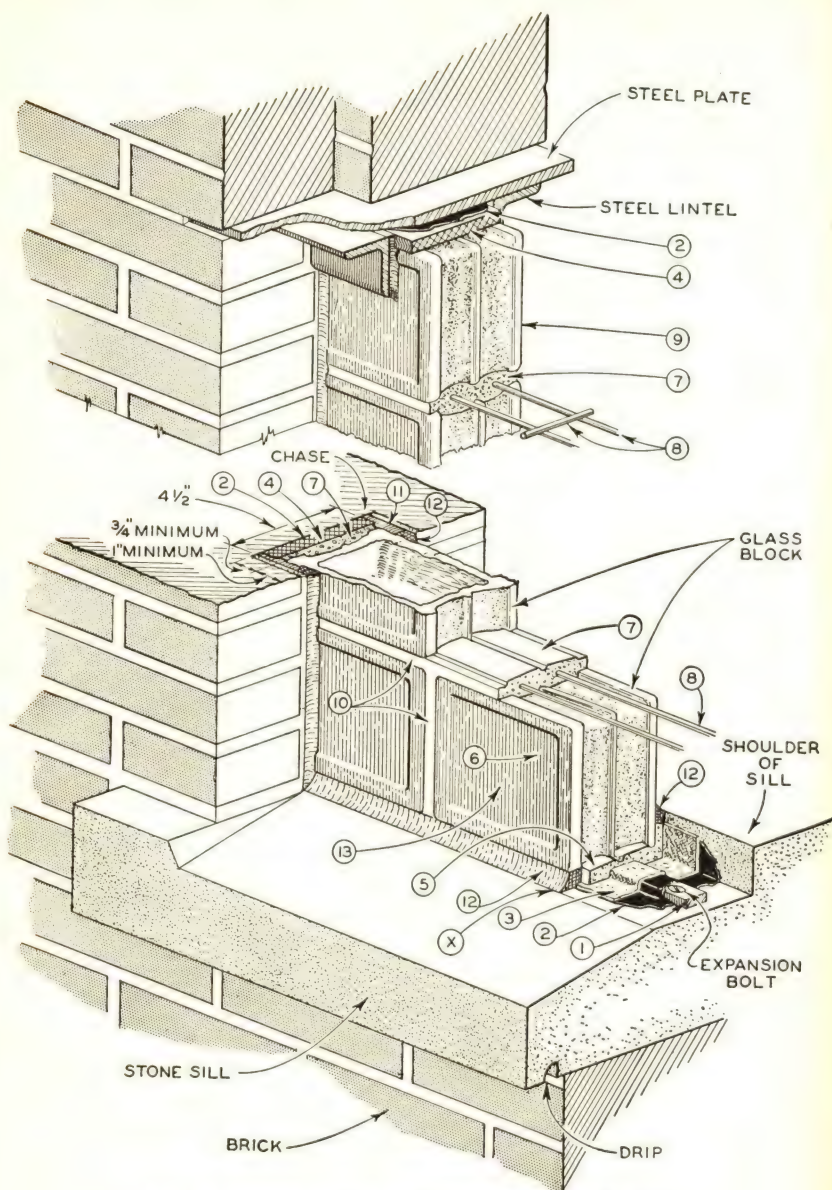
Fig. 30. Pictorial View of Glass Block Panel in Brick Wall

STEEL LINTEL

3/4" (NOT LESS THAN LINTEL DEFLECTION)

3/8" MINIMUM

MASTIC CALKING

SECTION X-X

BRICK OR TILE

WALL ANCHORS EVERY FOURTH COURSE

CORNER BEAD

1/4" MINIMUM

MORTAR IN SOLID

WALL TIES EVERY FOURTH COURSE

SECTION Y-Y

(A)

GLASS BLOCK

MORTAR IN SOLID

1/4" MINIMUM

MORTAR

CORNER BEAD

BRICK OR TILE

PLASTER

SECTION Z-Z

(B)
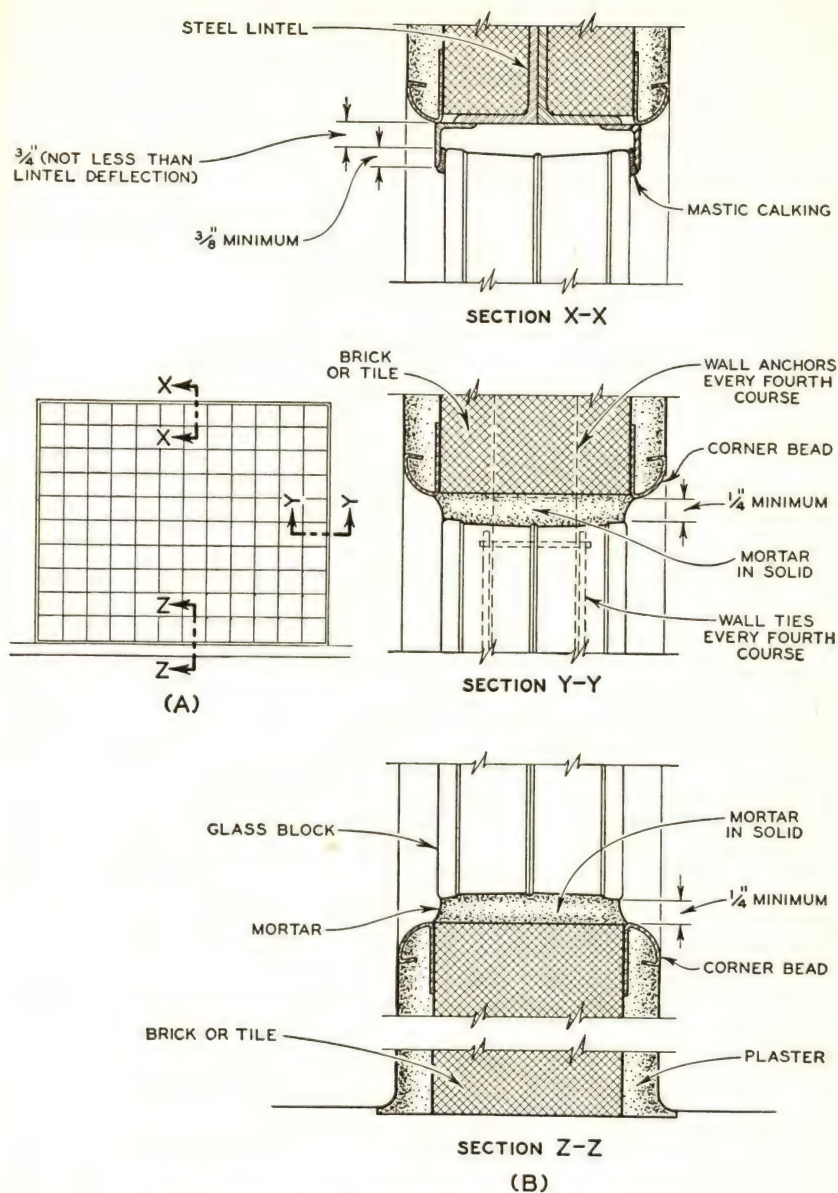
Fig. 31. Details of Glass Block Panel in a Masonry Partition
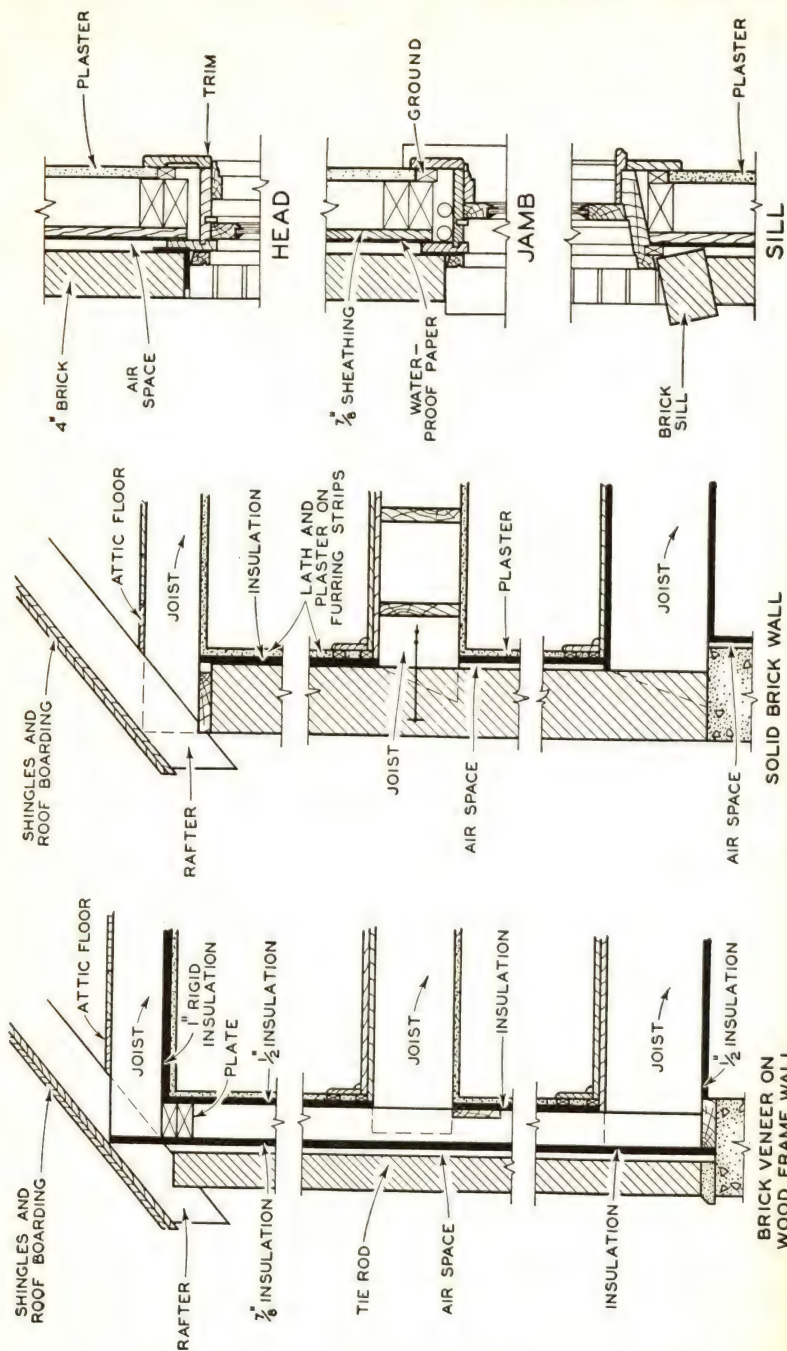
Fig. 32. Typical Brick Residence Walls
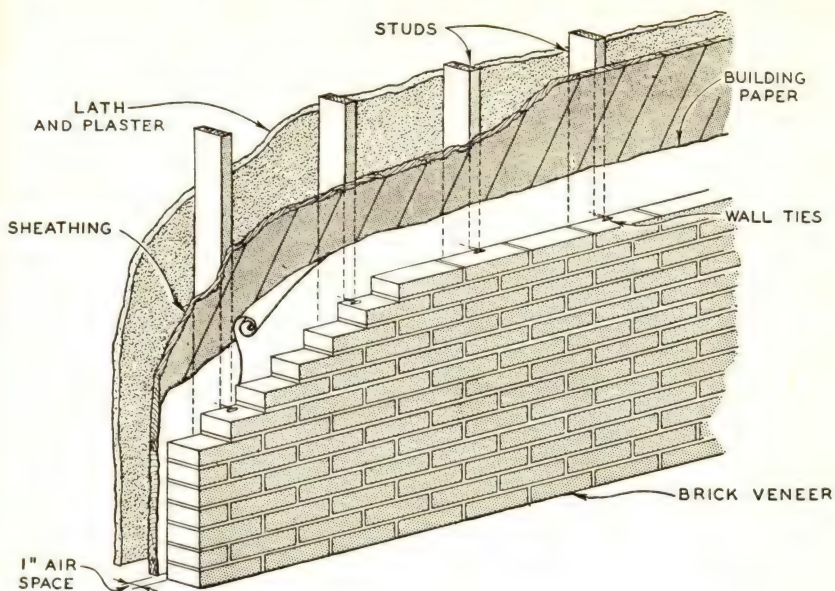
(A)
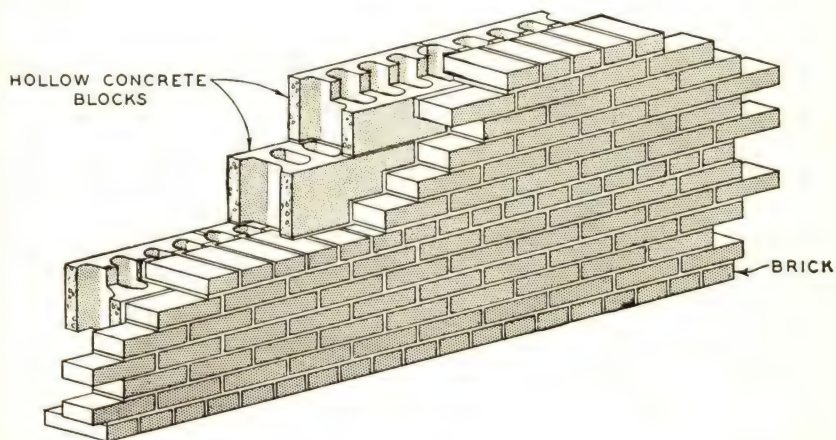
(B)

Fig. 33. Pictorial Views of Brick Veneer on Frame and on Concrete Block Walls

to the wood frame as shown in (A) of Fig. 33 and there must be a 1″ air space between them and the sheathing. Brick veneer is placed on a masonry wall as shown in (B) of Fig. 33 and as previously illustrated in Fig. 26.

Note that brick veneer on a frame wall consists of stretcher bonding throughout, whereas, when used with a masonry wall, it can be bonded by headers every sixth, fifth, etc. course, depending upon the masonry unit used in the principal part of the wall. Such brick may be either clay or concrete.

For the most part, brick veneer is used for residences. In some instances, garages, stores, and other small buildings have such walls. Apartment buildings and other such larger structures must have solid walls.

Brick veneer sometimes serves a very useful purpose when old residences are being remodeled and modernized. By the simple process of adding about 5″ to the outside of the foundation, brick veneer can be constructed over any type of wood frame wall or over any type of masonry wall.

Whenever brick veneer is used, lintels must be put over all window and door openings. For remodeling work, it is recommended that the veneer be started at points about 12″ below the top of the foundation.

Stucco walls. Like brick veneer, stucco can be applied over a frame wall or any type of masonry wall. Fig. 34 shows such applications. The use of stucco exterior wall surfaces is especially advantageous when used in conjunction with clay tile or concrete blocks. Fig. 35 illustrates typical details of the use of stucco on masonry walls.

Stucco walls are used for residences and many other small buildings. For the most part, this kind of wall is used in southern or southwestern parts of the country because of its architectural effect. This kind of wall seems better fitted to milder climates where severe temperature changes do not occur.

Stone Walls. Natural and artificial stone frequently are used as a veneer over wood frame or masonry walls in much the same manner as brick veneer. The stone can be purchased in units which are usually 4″ in thickness and of varying heights and widths. Aside from its use as a veneer, the employment of stone in residences and other small buildings is generally confined to sills for windows and doors, copings for

(A)

(B)
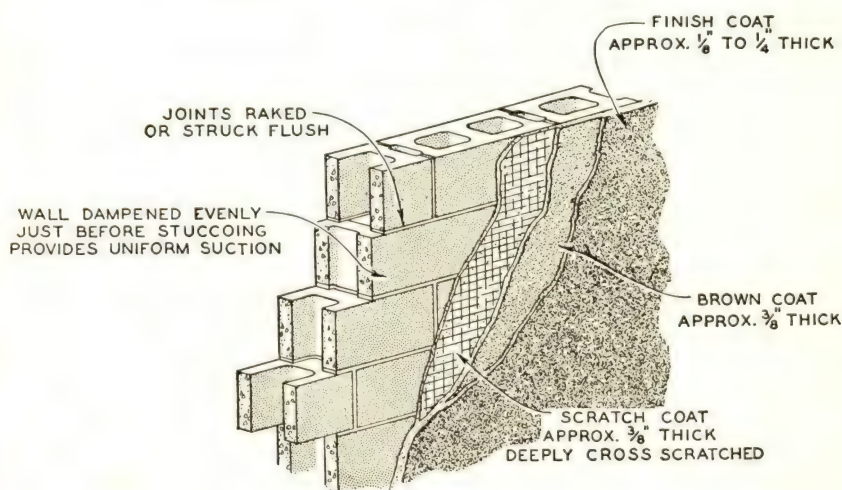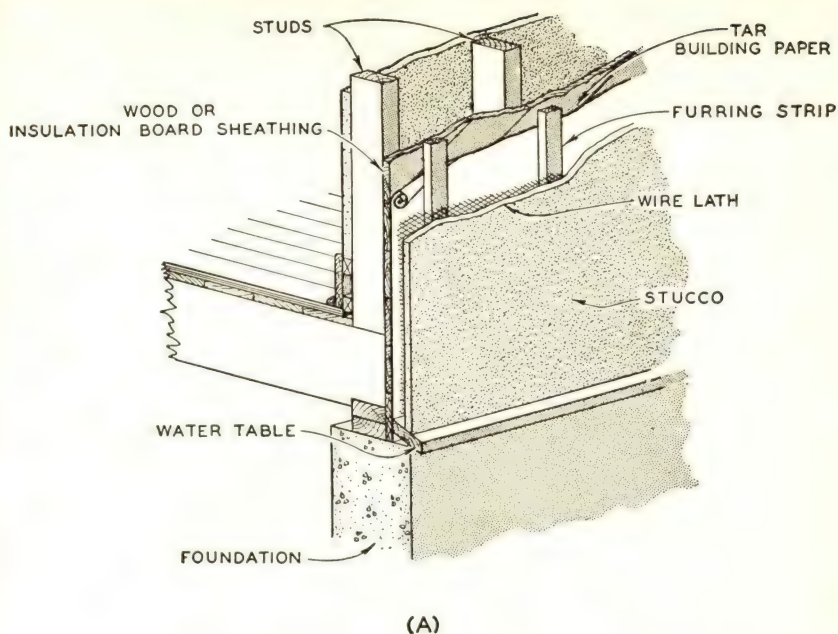
Fig. 34. Stucco Wall on Wood Frame and Concrete Block Walls
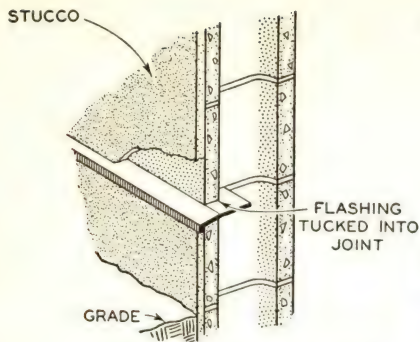
METHOD OF STOPPING STUCCO
WHERE NO BELT COURSE OR
SOLDIER COURSE IS PROVIDED
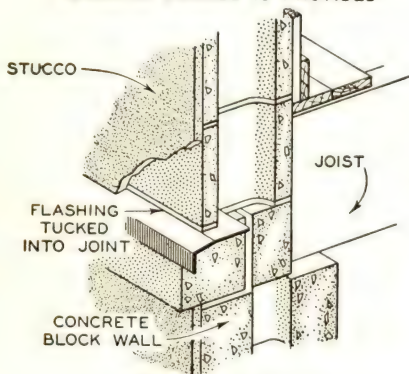
DETAIL OF FLASHING
WATER TABLE OR BELT COURSE
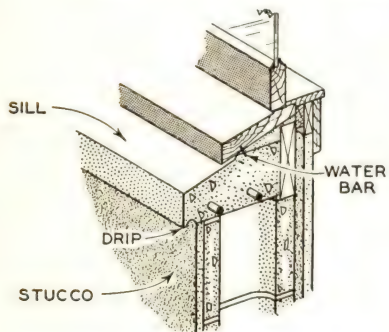
HEAD

DETAIL OF STUCCO
AT WINDOW SILL
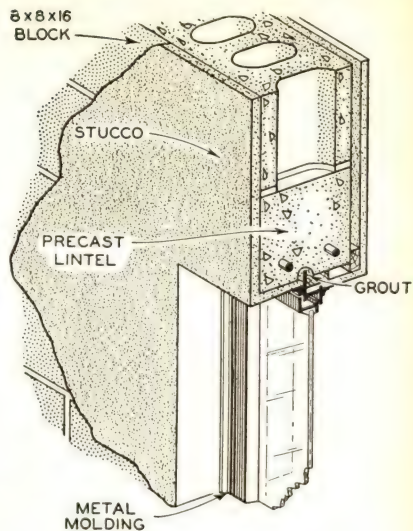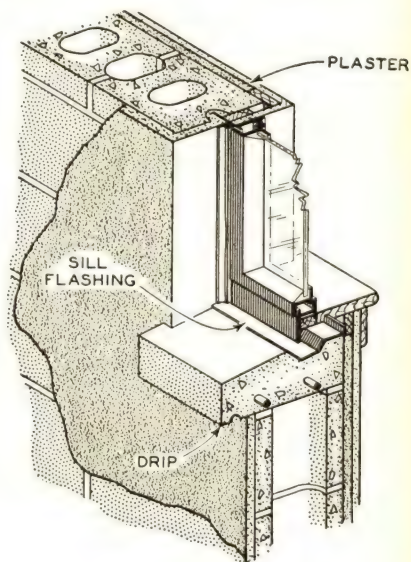
SILL

DETAIL OF STUCCO
AROUND WINDOW

Fig. 35. Window and Wall Details for Stucco Construction

parapet walls, and various ornamental lintels, steps, corner pieces in walls, and decorative pieces in groups, or singly, at various points in brick walls. Fig. 36 shows how stone is used as ornamentation in the brick wall of a residence.

Miscellaneous Walls and Partitions. There are many different kinds of veneers in addition to those just described which are available for

Fig. 36. Use of Stone as Ornamentation in Brick Walls

use in both walls and partitions. An example of these partitions and walls is shown in Fig. 37. The veneer on such walls is composed of glazed bricks, of which one face only has been treated. These bricks, and other similar units, can be obtained in many colors and make beautiful surfaces for basement recreation rooms, laundries, dairy buildings, and other similar structures.

DESIGN OF WALLS AND PARTITIONS

In practically all cities and towns throughout the country there are building codes or laws which state specifically the kinds of walls and partitions which may be used under certain conditions, together with their required thickness and other direct specifications. Therefore, if the reader intends to carry on masonry work in a locality where a
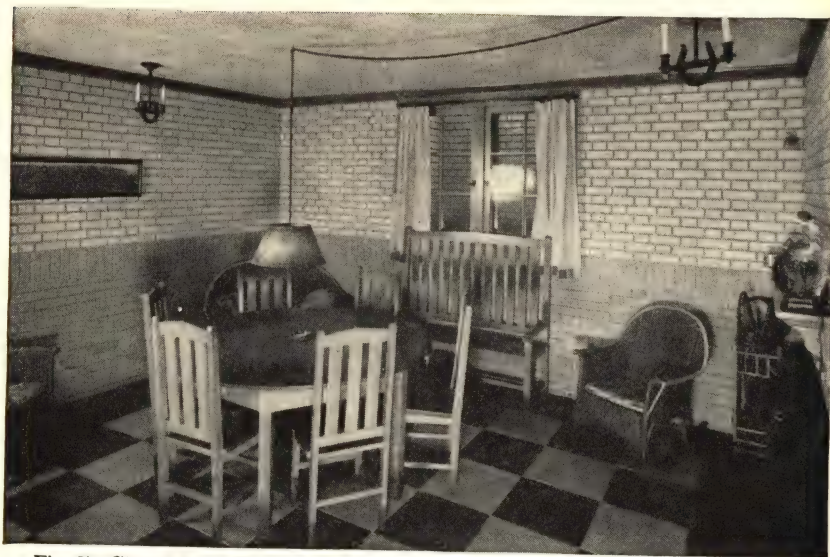
Fig. 37. Glazed Brick Used in Walls and Partitions of Basement Recreation Room

building code is in force, the dictates of the code should be followed rather than the suggestions contained in the following paragraphs.

The scientific design of masonry walls and partitions requires a rather complicated mathematical treatment, most of which has been avoided in this chapter because of the fact that most masons and other people interested in masonry work are not prepared to deal with it. Instead of mathematical treatment, this chapter presents certain rules and suggestions for wall or partition thicknesses and construction which have been proven sound by experience and repeated use. Should design problems beyond such rules or suggestions be encountered, it will be necessary to consult a structural engineer.

CONCAVE   "V"   WEATHERED

Fig. 38. Approved Types of Tooled Mortar Joints

Joints between Masonry Units. The joints between masonry units should be made carefully in order to assure strong walls which are capable of resisting the passage of water through them. Fig. 38 shows the
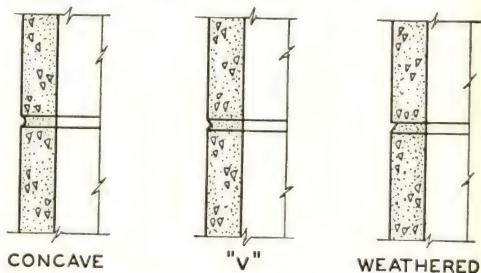
approved types of tooled mortar joints, none of which should be less than ¼″ or more than ⅜″ in thickness.

As the walls are being laid up, the joints should first be struck off flush with the surface of the masonry. When the mortar is partially set, the joints are compressed and compacted with a pointing tool to form one of the approved joints.

If, as is sometimes the case, it is desired to obscure all mortar joints between concrete units, they should be troweled flush and rubbed with a fragment of broken unit to compact the mortar and obscure the joint. Sheen may be removed by rubbing the joints with a piece of carpet or burlap.

Solid Brick Walls. The American Standard Building Code Requirements for Masonry[1] and the National Bureau of Standards recommend the following thicknesses for brick walls:

The thickness of masonry bearing walls shall be at least 12 inches for the uppermost 35 feet of their height, and shall be increased 4 inches for each successive 35 feet or fraction thereof measured downward from the top of the wall, except as otherwise permitted.

In residence buildings not more than 3 stories in height, walls may be of 8-inch thickness when not over 35 feet in height and the roof is designed to impart no horizontal thrust. Such walls in 1-story residence buildings, and 1-story private garages, may be of 6-inch thickness when not over 9 feet in height, except that the height to the peak of a gable may be 15 feet.

Solid brick walls should be supported at right angles to the wall face at intervals not exceeding 20 times the nominal wall thickness when laid in recommended mortar. Such support is given by chimney structures, corners of buildings, reinforced concrete floors, interior masonry partitions, or by special pilasters. The use of pilasters, except in long store buildings, is seldom required. When pilasters are needed, they should be square in cross section and twice as thick as the walls they stiffen or support.

The top plates upon which rafters and ceiling joists have their bearing should be bolted to the wall by the use of anchor bolts as shown at the top of the wall section in Fig. 12.

Where floor joists have their bearing in brick walls they should be

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[1] Available as Miscellaneous Publication 211 from the U.S. Department of Commerce, Washington, D.C.

cut as shown in Fig. 12. Each joist should have a bearing of at least 4 inches. Cutting or beveling the ends of the joists is done to prevent harm to the wall in the event of a fire. If for any reason one or more of the joists fail and drop down, they would fall in the direction of the arrow at X in the section view of Fig. 12, without damaging the wall.

The bond used depends primarily upon the architectural effect that is desired. Any of the bonds shown in Fig. 11 provides the necessary structural bonding.

For ordinary brick walls, a mortar mix of 1:1:6 is amply strong and resistive to the passage of water through walls.

Solid Brick Partitions. A 4″ wall is sufficiently strong when adequate lateral support is provided. The same conditions prevail, regarding partition stability and lateral support, as those affecting walls. For an example of brick partition design, refer to Fig. 2. As previously explained, brick partition GF supports the ends of joists L, M, P, R, S, and T. These joists support the first floor as well as the bearing partitions above them. These bearing partitions in turn support the second floor and attic loads. Suppose this partition must support a load of 3,000 pounds per lineal foot. The load per square inch on the partition is then $\dfrac{3,000}{4 \times 12} = \dfrac{3,000}{48} =$ approximately 63 pounds.

It is known that brick can support many times this load (unit stress) when it acts directly downward as a compressive load. The 4″ partition, therefore, is safe. However, lateral support is absolutely necessary and is provided by the pilaster at G, partition HK, and the intersection with the foundation at F.

It should be remembered that many local building codes do not allow 4″ bearing partitions under any circumstances. Under such restrictions an 8″ partition would have to be used for GF.

Nonbearing brick partitions can range in thickness from 2¼″, as in (B) of Fig. 13, up to and including 8 inches. The 2¼″ partition should not be used where heavy fixtures such as sinks must be supported, or where severe bumps might be expected, as in a coal bin. For other than closet enclosures or for short partitions having ideal conditions of lateral support, the 4″ partition is recommended.

All openings in partitions should have reinforced masonry or steel lintels across them. The bond recommended for such walls is shown in

(A) and (B) of Fig. 13. The bond shown in (A) of Fig. 10 is recommended for 8″ partitions. A 1:1:6 mortar mix is recommended.

Pier and Panel Economy Brick Walls. This kind of wall is intended primarily for one story residences and for small garages, gasoline service stations, and other minor buildings in which the walls need not carry heavy loads. In fact, these walls should not be subjected to loads greater than those coming from short span ceiling joists and roof rafters. Most building codes do not allow this kind of wall in other than one story buildings.

Such walls (shown in Figs. 14 and 15) are 4″ thick and are built of brick laid flat in common bond, supported by pilasters 8″ square. Figs. 39 and 40 show the recommended design. Note that the pilasters are approximately 3′10″ from center to center. It is recommended that the inside surface of such walls be plastered with mortar as indicated in course A of Fig. 39.

Fig. 39 gives the recommended design of various courses. Fig. 40 shows these courses in elevation. As shown in Fig. 15, pilasters should be erected against the inside wall on both sides of all window and door openings. From Figs. 39 and 40 it can be seen that 8″ construction is recommended at all sills, girts, and plates. There should be 2 x 2 furring strips between pilasters. Furring strips placed directly on the pilaster should be ⅞″ x 1½″. These strips are shown in the plan view of Fig. 40.

The bonding recommended for such walls is shown in both Fig. 39 and Fig. 40. The mortar for such walls should not be weaker than a 1:1:6 mix.

Rolok Walls. Eight-inch rolok-bak and all-rolok walls such as shown in Figs. 17 and 18 may be used for one and two story residences and other small buildings in the same manner as 8″ solid brick walls. Walls of these kinds in 12″ thicknesses may be used the same as 12″ solid brick walls for apartment and other such buildings where only moderate loads must be supported. The use of these kinds of walls for buildings of more than three stories or for buildings where heavy loadings must be supported should not be planned without the assistance of a structural engineer.

Anchors, shown in the section view of Fig. 18, should be built into the two top continuous header courses. Joists should also be anchored as shown.
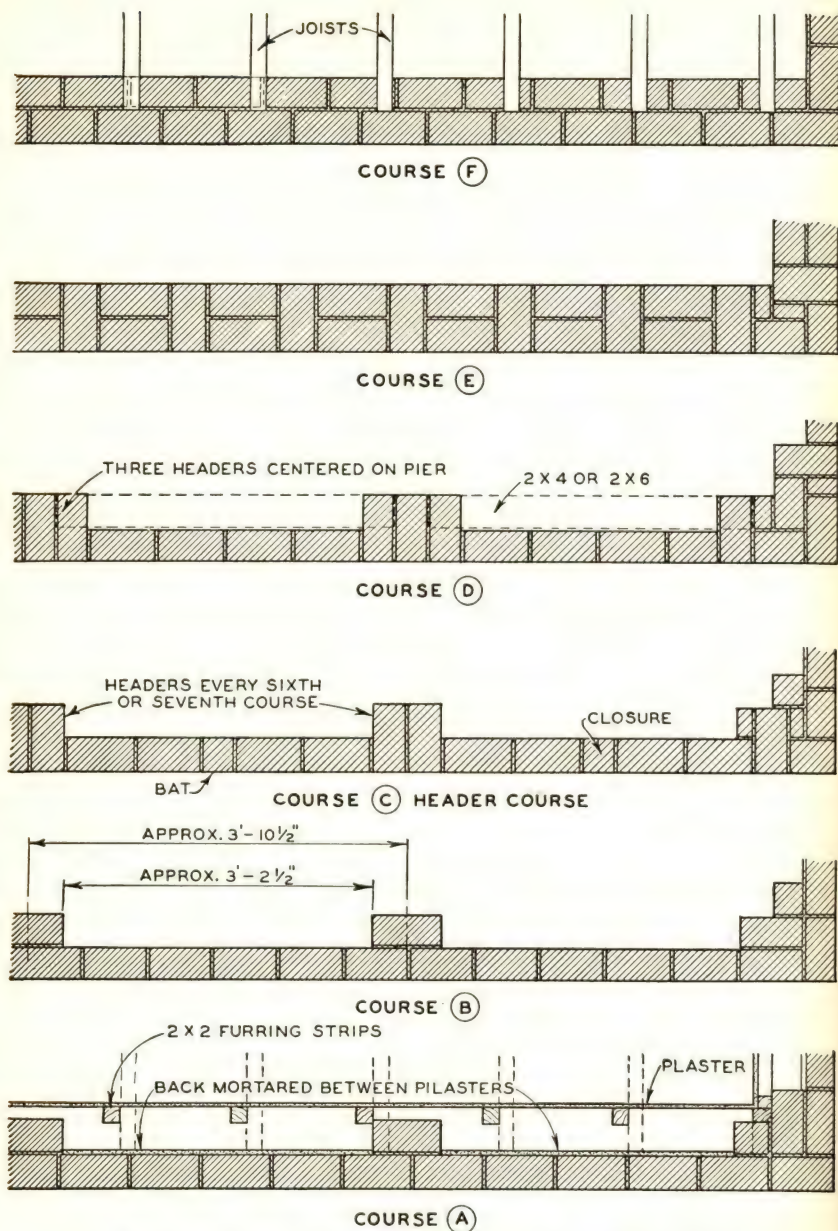
Fig. 39. Plan Showing Construction of Economy Wall by Courses

FIRE STOP

COURSE (F)

COURSE (E)

COURSE (D)

COURSE (B)

2 X 4

FIRE STOP

ELEVATION

WHEN FURRING OCCURS
AT PILASTER USE ⅞" X 1½" STRIPS

2X2 FURRING

PLAN
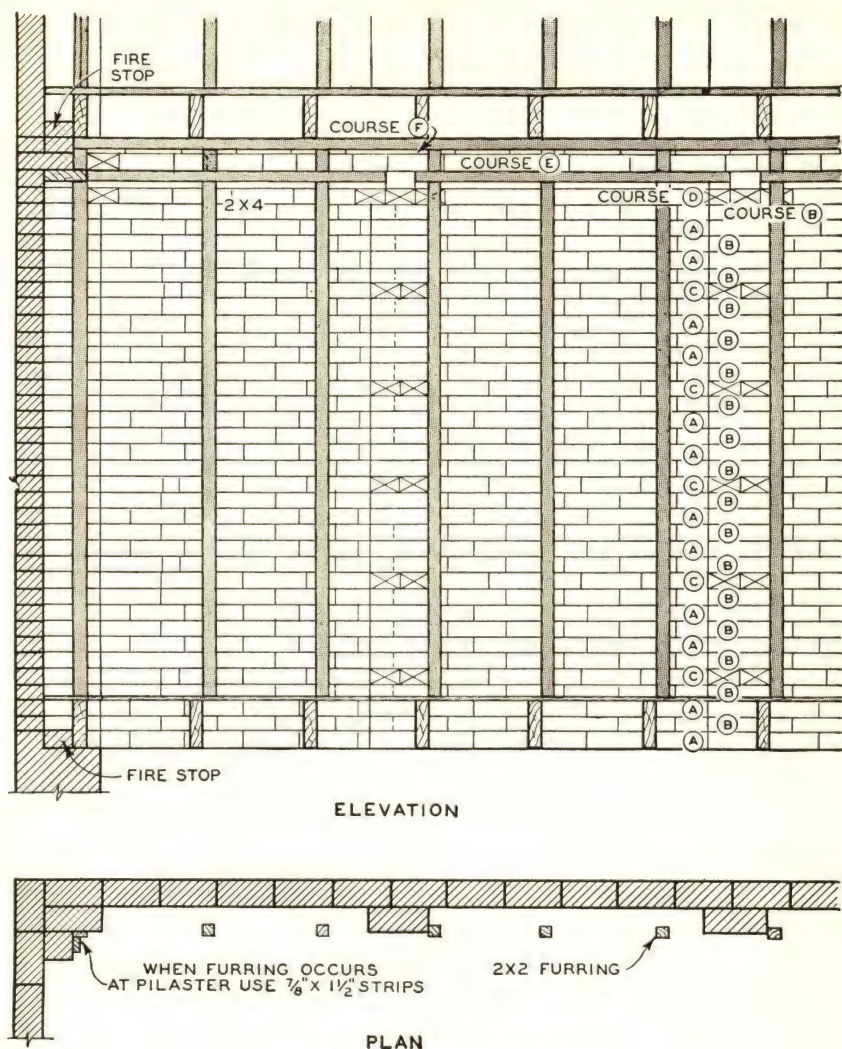
Fig. 40. Elevation of Economy Wall

Where joists have their bearing in rolok walls, the bearing surfaces in the walls should be composed of header courses and each joist should have at least 4" of bearing. Those bonds shown in Figs. 17 and 18 are recommended. Lateral support should be provided, especially for 8" walls of this kind. A mortar mix of 1:1:4 is recommended.

Brick Cavity Walls. This kind of wall can be used the same as an 8″ brick wall except that the maximum permissible height is only 25 feet. Neither the facing nor the backing in these walls should be less than 3¾″ in nominal thickness, and the cavity should not be less than 2″ nor more than 3″ in width.

As shown in Figs. 19 and 20, the facing and backing should be securely fastened together with steel ties which are coated with some non-corroding protective agent. Note the method of installation for the anchor plate bolts in the section view of Fig. 20.

Joists should have a full 4″ of bearing in the backing tier and should be tied by the use of joist anchors. The bond shown in Figs. 19 and 20 is recommended with a 1:1:4 mortar mix.

Tile Walls. Light tile walls such as shown in Figs. 21, 23, and 24 can be used for one and two story residences, small storage buildings, garages, service stations, small commercial structures, and all types of farm buildings. Fig. 22 shows a modern barn and silo which have 8″ tile walls. The wall in (A) of Fig. 24 is for barns such as shown in Fig. 22 while the wall in (B) is for a residence.

For very large barns and for buildings over two stories high or where exceptionally heavy loads must be supported, 12″ tile walls are necessary. However, it is recommended that a structural engineer be consulted for any construction beyond the use of 8″ tile walls.

Note in Fig. 24 that plate anchor bolts are required and that joists, besides having 4″ bearing surfaces, should be tied to the walls by anchors. Note, too, that under all bearing points in tile walls, solid masonry such as that under the joists in (B) or special multicelled units as the X header in the section at (A), must be used to distribute the loads over greater areas in the walls. Bonding such as shown in Figs. 21 and 22 is recommended.

A mortar mix of 1:1:4 is suggested because of face shell bedding. Lateral support must be provided.

Tile Partitions. Tile bearing partitions are generally from 4″ to 6″ thick. The 6″ thickness is recommended under most conditions. When only ceiling joists and rafters must be supported by tile bearing partitions in small buildings, the 4″ thickness will be sufficient. Where floor loads above such partitions must be supported as in the case of partition GF in Fig. 2, then the 6″ thickness should be used.

When using tile partitions similar to the one shown in Fig. 21, it is recommended that two courses of bricks be laid at the top of the partition as a means of distributing the loads from the joists more efficiently.

Nonbearing tile partitions can be made from 2″ to 4″ in thickness using any one of the many available types of tile. It is suggested, however, that 4″ partitions be used where plumbing fixtures must be supported or where any other side strain may be encountered. Bonding is recommended such as that shown in Figs. 21 and 25.

For tile walls which provide full bedding, a 1:1:6 mortar is satisfactory. For celled units, however, the 1:1:4 mortar is suggested.

Brick and Tile Walls. Eight and 12″ thicknesses of this kind of wall can be used in the same manner as like thicknesses of solid brick walls. All of the design data explained for solid brick walls applies equally well to this kind of wall.

Glass Block Panels. As has been previously explained, glass blocks are incapable of supporting any weight other than their own. Governed by this limitation, glass blocks can be used only to make up panels in walls and partitions. These panels are considered in the same manner as are door and window openings in that the masonry work above them must be supported by lintels.

Wall ties such as shown in Figs. 30 and 31 must be placed in every fourth horizontal mortar joint when 6″ or 8″ blocks are used, and in every horizontal joint when the 12″ block is used. These ties should be embedded in the mortar.

In Fig. 30 the panel jamb is held securely in place by a chase in the wall. However, in Fig. 31 there is no chase so the jamb must be held in place by wall anchors which can be embedded in the partition joints as it and the panel are laid up. If such panels are built into existing walls, the jambs must be secured as shown in Fig. 41.

When panels are laid up along with other parts of walls, the lower courses can be secured to the sills by lock bars. An example of the lock bar can be seen in Fig. 30. If, however, the panels are to be laid up in old window openings, the procedure is as shown in Fig. 42.

The lengths and heights of glass block courses must be carefully planned for new walls, and to fit existing openings to the best advantage. Such lengths and heights can easily be calculated if the mortar joint thickness and block sizes are known.

Provisions for expansion must be made at all jamb and head sections of panels in walls. This is done by using expansion strips such as shown in Figs. 41 and 42. No such provisions are required for panels in partitions. However, in partitions, provisions must be made for lintel deflection. Such a provision is indicated by section *X–X* in Fig. 31.

All panels in walls must have jamb, sill, and head sections calked to prevent the passage of moisture. This calking is shown in Figs. 31, 41, and 42. A mortar mix of 1:1:4 to 1:1:6 is recommended. For panels
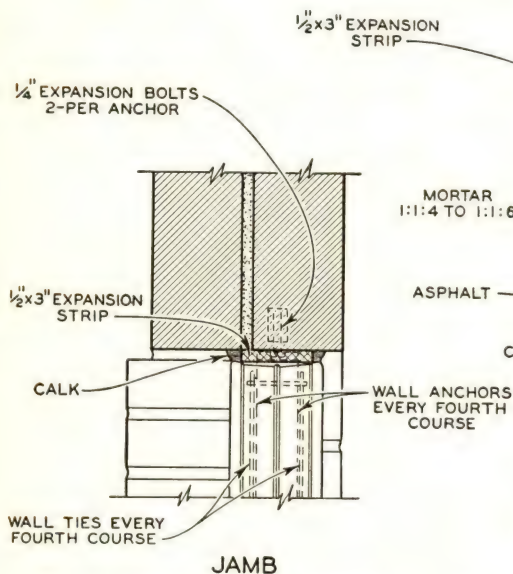
Fig. 41. Glass Block Panel Anchored
by Expansion Bolts
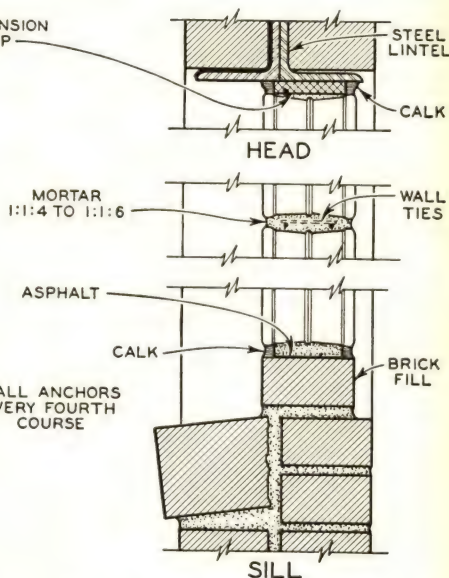
Fig. 42. Glass Block Panel Built in
Old Window Opening

in walls, the mortar should contain an integral metallic stearate type of waterproofer. This material should be added to the mortar at the time it is mixed.

Concrete Block Walls. For one and two story residences, small store buildings, garages, barns, and other similar farm buildings, 8″ concrete block walls can be used. Other walls can be built using blocks or units of various sizes. An 8″ concrete block wall compares favorably with an 8″ brick wall in strength and the possible uses to which it may be put.

If other than those buildings described in the preceding paragraph

are built, the walls should be increased in thickness. The United States Bureau of Standards recommends that three story buildings should have 12″ thick walls up to the second story level and 8″ walls for the third story. Similarly, a four story building should have 16″ walls up to the second floor and 12″ walls for the second, third, and fourth stories.

Veneered Walls. When brick veneering is used in conjunction with frame buildings, the wood frames carry the necessary loads while the veneering, which is secured laterally by the wood frames, is supported by the foundations. Therefore, the only designing required involves providing a foundation which will be adequate for the support of the veneer, making the selection of color and surface texture of the brick to be used, and deciding upon the joint treatment. If such veneering is bonded into tile or concrete block walls, it is considered as part of the walls.

BRICK VENEER ON OLD FRAME BUILDINGS. As previously suggested, old frame buildings such as residences can be modernized by adding brick veneer to their walls. This is not a difficult task and can be accomplished with little change of the existing walls. The veneering should be supported by the foundation which must, in most cases, be added to the existing foundation. There are several methods of providing the new foundation, three of which are explained in the following paragraphs.

In (A) of Fig. 43 is shown a common type of sill and foundation for a wood frame wall. The drawing at (B) in Fig. 43 illustrates one method of providing a foundation for the brick veneering. Note that the new section of foundation is supported by the old footing and that it extends only slightly above grade. Another method of providing a foundation for brick veneering is shown in (C) of Fig. 43. Note that this method requires the use of steel tie rods which are embedded in the new section of the concrete foundation and fastened to the old by means of expansion bolts at point X. These tie rods make certain the new foundation does not settle, causing the brick veneer to crack.

A third method of supporting the brick veneer is by means of steel shelf angles which are bolted to the foundation. The veneer is then laid directly on the angle. This latter method is the least desirable of the three methods suggested.
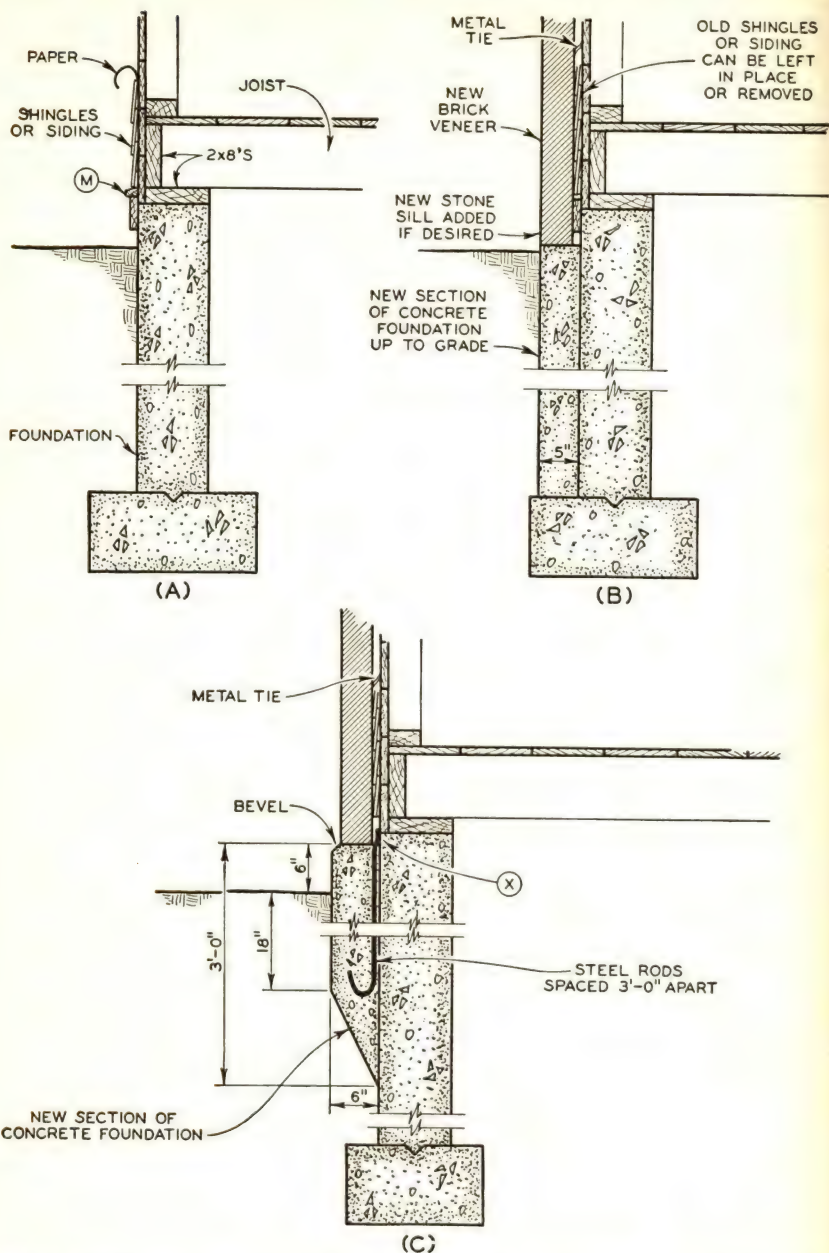
Fig. 43. Typical Methods of Providing Foundations for Brick Veneer over Old Frame Walls

Brick veneer should be at least 1″ and not more than 2″ from the shingle or siding surface of the old wall. It may be necessary to remove such projecting pieces of millwork as the watershed shown at *M* in (A) of Fig. 43.

The veneer must be tied to the old wall by the use of noncorrodible metal ties spaced 16½″ apart vertically and 16″ apart horizontally. Tar paper or some other heavy building paper should be nailed to the old wall surface as the veneer is laid up. The metal wall ties used in brick veneer construction can be seen in (A) of Fig. 33.

Around window openings, the veneer is set as illustrated in the brick veneer window details section shown in Fig. 32. Note, for example, how the new brick sills are set under the wood sills of the window. Steel lintels are necessary to support the veneer over all window and door openings. In some cases new window and door frames must be put in. Carpenters or representatives of lumberyards should be consulted for advice when necessary. At the cornice the veneer is usually continued until it is housed by the rafters and other cornice members.

Stucco Walls. When stucco wall surfaces are to be applied over wood frame walls, 1 x 3 furring strips must be nailed vertically, 16″ center to center, to the wood or insulation board sheathing. This is illustrated in (A) of Fig. 34. Metal lath should then be securely nailed to the furring strips. The stucco is applied to the metal lath. The wood frame of the wall supports the necessary wall loads. The only design problems to be considered regarding stucco is in the choice of mortar color and surface texture.

When stucco surfaces are desired for masonry walls, they are applied directly to the masonry as pictured in (B) of Fig. 34.

Openings in Masonry Walls. All openings in walls built of masonry units should be carefully planned as to size and location so as to avoid the necessity for cutting any of the units in order to make them fit. Suppose, for example, that a window or door opening was located so that every unit at the jambs had to be cut to some other than standard length in order to fit them into place. These cut units would spoil the appearance of the bonding. If such openings were placed so that the units had to be cut to fit properly at the heads and sills, the bond appearance again would be spoiled. Also considerably more labor would be involved.

Lengths and Heights of Brick Walls. Table II gives the number of standard bricks (using a ⅜″ mortar joint) in courses of various lengths as well as the heights of these courses. This table can be used in planning the sizes and locations of all openings in brick walls so as to avoid the necessity for cutting bricks at the jambs, heads, and sills of doors and windows.

TABLE II. LENGTHS AND HEIGHTS OF BRICK COURSES LAID WITH 2¼″ x 8″ BRICK AND ⅜″ MORTAR JOINT

NUMBER OF BRICKS	LENGTH OF BRICK COURSES	HEIGHT OF BRICK COURSES
1	8⅜″	2⅝″
2	1′ 4¾″	5¼″
3	2′ 1⅛″	7⅞″
4	2′ 9½″	10½″
5	3′ 5⅞″	1′ 1⅛″
6	4′ 2¼″	1′ 3¾″
7	4′ 10⅝″	1′ 6⅜″
8	5′ 7″	1′ 9¼″
9	6′ 3⅜″	1′ 11⅝″
10	6′ 11¾″	2′ 2¼″
11	7′ 8⅛″	2′ 4⅞″
12	8′ 4½″	2′ 7½″
13	9′ ⅞″	2′ 10⅛″
14	9′ 9¼″	3′ ¾″
15	10′ 5⅝″	3′ 3⅜″
16	11′ 2″	3′ 6″
17	11′ 10⅜″	3′ 8⅝″
18	12′ 6¾″	3′ 11¼″
19	13′ 3⅛″	4′ 1⅞″
20	13′ 11½″	4′ 4½″
21	14′ 7⅞″	4′ 7⅛″
22	15′ 4¼″	4′ 9¾″
23	16′ ⅝″	5′ ⅜″
24	16′ 9″	5′ 3″
25	17′ 5⅜″	5′ 5⅝″

NOTE.—For other than ⅜″ joints, calculations can be made to arrive at the lengths and heights of courses. Merely add the thickness of one mortar joint to the length or height of the brick and multiply by the number of bricks in the course.

Lengths and Heights of Concrete Masonry Walls. The lengths and heights of masonry walls also must be carefully planned so that standard units can be used without there being a need for cutting some of them to fit. The consistent use of whole units creates the proper bond and makes a pleasing appearance. In order to insure the use of whole units in a wall, it is sometimes necessary to alter the length of the wall slightly. For example, if one wall of a proposed small brick building were 16′ 3″ long and ⅜″ mortar joints were to be used, it would be advisable to increase the length of the wall to 16′ 9″ since, according to Table II, this dimension is equivalent to 24 whole bricks. Because the

last joint of ⅜″ is not necessary at a corner or end of a wall, the actual wall length is 16′ 9″—⅜″, or 16′ 8⅝ inches.

The lengths and heights of walls built using other masonry units should be planned with just as much care so as to assure a good appearance with the least amount of labor.

BUILDING WALLS AND PARTITIONS

Many of the techniques or methods used in laying brick, stone, tile, concrete blocks, etc., have been explained in previous chapters and thus need not be repeated here.

Solid Brick Walls. All solid brick walls must be supported by adequate foundations or footings. Where concrete foundations are used, the concrete should be allowed several days to two weeks for hardening before brick work is started, depending on whether it was poured in warm or cold weather. If both the walls and the foundation are to be of brick, they can be laid continuously.

The walls are laid up to the level of the first joists. The joists should then be placed and termite shields installed if they are thought necessary. Care should be taken to see that the joist ends are beveled properly, that they are spaced correctly, and that no more than 4″ of bearing surface is allowed. When the joists have been placed, the outside wythe is built up course by course and the interior wythes laid around the joist ends. It will be necessary to cut some bricks in order to make them fit over the beveled ends of the joists.

When building walls which have window and door openings, bricks are laid up on both sides of the openings as shown in Fig. 12. When the jambs have reached the height of the opening, the lintels are carefully set, care being taken to make certain they are laid in mortar. Some of the bricks may have to be chipped slightly in order to make them fit tightly above the lintels. Mortar should be applied to the lintels before setting the first course of bricks on them. The lintels should be placed so that the exterior edge is slightly behind the outside edge of the exterior wythe.

All walls of a building should be laid up at the same level all the way around because of the placement of joists and to provide lateral support. Anchor bolts should be embedded in the joints. If they are too big for the joints, bricks around them are chipped as necessary.

Solid Brick Partitions. Bearing partitions such as *GF* in Fig. 2 must have adequate footings. Nonbearing partitions such as *GJ* and *HK* in Fig. 2 also should have footings. The minimum footing, 12″ wide and 8″ deep, should be ample. Nonbearing partitions should never be set on concrete basement floors as the latter are apt to crack and settle, thus causing the partition to be badly cracked or to fail completely.

Pier and Panel Economy Brick Walls. This kind of brick wall requires a foundation, the thickness of which is somewhat greater than that of the piers. This is shown in the section view of Fig. 15. Figs. 39 and 40 show in detail the manner in which the various courses for this kind of wall are laid. These drawings are self-explanatory. Figs. 15 and 16 show other details which can be used in laying up such walls.

When the panels have been laid, they should be back plastered (back mortar) to a depth of at least ½″, using regular mortar.

Rolok Walls. The laying of rolok walls, including window, door, and other details such as foundation requirements, etc., is similar to the laying of other kinds of brick walls.

Cavity Brick Walls. Cavity brick walls are simple to lay in that the brickwork is not complicated and follows the general methods previously explained.

Tile Walls. Tile walls can be built on either tile or concrete foundations. When joists bear in tile walls, as shown in the section views of Figs. 23 and (B) of 24, either solid masonry units are placed under the joist bearings or the cells in the tile are filled with concrete. This practice is necessary to provide more strength under the joists and to better distribute the load from them. The tile around the joists are either set in smaller units as in Fig. 23 or the standard sized unit may be used as shown in (B) of Fig. 24.

The top tile course in a tile wall, as shown in Figs. 23 and (B) of 24, also should be composed of solid masonry units or the cores in the regular tile should be filled with concrete to provide stronger bearing for roof rafters and to securely hold the anchor bolts. Joists, as shown in (B) of Fig. 24, may be anchored by means of strap anchors which are embedded in the joints between the tile units.

Figs. 21, 23, and 24 show typical details for laying tile walls in small buildings such as residences and barns.

Tile Partitions. Tile partitions constructed of units similar to those illustrated in Fig. 21 are laid up following the same procedures described for tile walls.

It is recommended that the lintels over door openings be either steel or reinforced tile. (See the head section of the window details in Fig. 23.) Wood lintels should never be used. Tile partitions, whether bearing or nonbearing, should never be used above the basement in a wood frame house and must always have adequate footings.

Note the lintel over the door opening in Fig. 25. This lintel can be made on the job by cutting regular units to form the arch. Openings greater than 4' 0" should be spanned by steel lintels as for ordinary partitions.

Brick and Tile Walls. Laying up brick and tile walls is done following the same explanations given previously. Figs. 26 and 27 show construction details which are typical of all such walls.

Glass Block Panels. The following glass block installation procedures are numbered. These numbers refer to the circled figures which have been included in Fig. 30.

1. Secure the 1¼" x 1¼" lock bar to the sill using ⅜" flathead expansion bolts spaced 24" on centers. Lock bars can be purchased from glass block manufacturers. The expansion bolts screw into holders which should be placed in the sill during the time the sills are being laid up. Any type of such bolt can be used providing it has a flat head.

2. A heavy coat of asphalt emulsion should be applied to the jambs, head, and sill as shown at *2* in Fig. 30. Asphalt emulsion can be purchased from any building material dealer.

3. Roofers' felt is placed at the sill. The felt is stuck to the sill, over the lock bar, by the asphalt emulsion. Felt also can be purchased from any building material dealer.

4. Expansion strips are stuck to the jambs and head of the window opening using the asphalt emulsion. These strips are bought from the glass block manufacturers.

5. A full, unfurrowed mortar bed is placed on the sill.

6. The lower course of blocks is set. The blocks should be placed about ½" away from the shoulder of the sill to allow space for the mortar and calking. Each block should be tapped down so that it is firmly bedded in the mortar. The joint at the front of the sill should be left about ½" to allow for calking as at X. All vertical joints should be ¼" wide.

7. For joints not requiring ties, the mortar should be placed in full thickness. The amount of mortar required can be judged by experience.

8. Wall ties, which can be purchased from the manufacturers of glass blocks, are installed in horizontal joints as follows:

a) Half the quantity of mortar needed for the finished joint is placed on the blocks. The thickness required can be judged only through experience.

b) The metal wall ties are placed on the mortar.

c) The wall ties are covered with the rest of the mortar needed to complete the joint. This mortar is then troweled fairly smooth and the block is put in position as described in step *6*.

d) Wall ties must run from end to end of the panel in which they are used. If their length requires the use of two or more sections, the ends should be overlapped at least six inches. Wall ties should not bridge expansion joints.

9. The procedures described in steps *6, 7,* and *8* are followed in setting succeeding courses. The blocks are laid in a manner similar to the laying of concrete blocks except that the vertical joints are not staggered. Guide lines and the mason's level are used just as in laying other building units.

10. The joints are struck smoothly, as shown in Fig. 30, before the final set while the mortar is still plastic. At this time all joints requiring calking are raked out to a depth equal to the thickness of the joint. The surplus mortar is removed from the faces of the blocks and they are wiped dry.

11. After the final mortar set, oakum is packed tightly into the jamb and head construction as shown.

12. The interior and exterior perimeter of the panel is calked with compound. This material can be purchased from building material dealers.

13. The last step is the cleaning of the block surfaces but this is not done until after the final set of the mortar.

The mortar mix for glass blocks should be carefully prepared, remembering the fact that the blocks do not absorb moisture. Thus, the proper consistency for this mortar will be considerably drier than for ordinary bricks. Too dry a mix will result in weak and poorly bonded joints while a very wet mix will also produce a weak and porous joint which may develop shrinkage cracks. If mixes are made relatively stiff they will prove satisfactory.

Cleaning glass blocks during installation and regularly thereafter is important. During installation, a scum of cement, lime, and water is certain to smear the surfaces of the blocks. This scum is most easily removed if it is allowed to dry and is then wiped off with a *dry* cloth. The best time for such cleaning is at the same time that the mortar joints are pointed and tooled. This is usually four to five hours after the blocks have been laid. The final cleaning after the set of the mortar has taken place, consists of a washing down with a 10% solution of muriatic (hydrochloric) acid. This is immediately followed by a thorough, clear-water rinse to remove all traces of the acid. The usual deposits of air-borne dust and dirt are removed by wiping with a damp cloth. Where panels have stood for long lengths of time without

being cleaned, they should be washed with a mild solution of acid as previously described, then rinsed thoroughly with clear water.

Concrete Block Walls. Like all other masonry walls, those constructed of concrete blocks must have adequate foundations of either concrete blocks or concrete which has been poured in place. The use of reinforced concrete lintels in conjunction with concrete block walls has been explained in the chapter on beams and lintels.

Typical construction details involving the use of concrete blocks are shown in (B) of Fig. 33, (B) of Fig. 34, and Fig. 35. The actual laying of blocks and allied details have been thoroughly discussed previously and will not be repeated here.

Brick Veneer Walls. The veneer for new frame walls should not be started until the walls are fully erected and the wood or insulation board sheathing is in place.

The first brick course can be laid directly on the concrete foundation, or a stone sill, as shown in (B) of Fig. 43, can be used. As the brickwork progresses upward, tar or other building paper is nailed to the sheathing. The metal ties which anchor the masonry to the wall should be nailed to the sheathing and set into the mortar joints of the masonry. Typical window details for brick veneer masonry are shown in Fig. 32. The veneering on all walls should be laid up at the same rate so that they are always the same approximate height.

When brick veneer is to be applied to existing wood frame walls, the foundation method pictured in (B) of Fig. 43 is recommended. The actual construction procedures are simple and make for sound work.

In order to pour the 5″ addition to the existing foundation, the earth must be excavated so as to provide a working space approximately $2\frac{1}{2}'$ to 3′ in depth all around the house. It should be wide enough to permit easy erection of the forms.

The surface of the existing foundation must be carefully cleaned to remove all traces of earth from it. This is important because it insures that the new concrete will adhere to it. When the surfaces have been cleaned, a coating of grout (cement and water) should be applied to them by means of a mop or large brush.

Forms must be built to shape the exterior surface of the 5″ addition. These forms can be quickly and easily erected by using unit forms or panel units.

A concrete mix of 1:1:4 is recommended. The mix should be rather wet in order to pour easily into the narrow space. The concrete should be poured 6″ to 8″ at a time and should be carefully spaded to make certain that no voids have been left.

In warm weather the forms can be removed 4 to 5 days after pouring. In cold weather the forms should not be removed from 10 days to two weeks after pouring. Additional time should be allowed for the new concrete to dry before the veneer work is started. At least a week is suggested as a suitable length of time to wait. Backfilling can be done at any time after the forms have been removed. Care should be observed so that the new concrete is not struck with shovels or lumps of earth. The brickwork is carried on as described for new veneer work.

Stucco Walls. When stucco is to be applied to wood frame walls, as shown in (A) of Fig. 34, the exterior surface of the sheathing should be covered with tar or other building paper. The furring strips and metal lath are applied as previously described.

For masonry walls where stucco can be used to the greatest advantage (either tile, brick, or concrete block), the stucco is applied directly to the wall surface as shown in (B) of Fig. 34 and in Fig. 35. A three-coat stucco is recommended which consists of a first or scratch coat, a second or brown coat, and a finish coat. These three coats may be seen in the drawing at (B) in Fig. 34.

Mortar for all coats should be mixed in the proportions of one sack of Portland cement to three cubic feet of moist sand to which not more than ten pounds of hydrated lime or lime putty can be added to give the mix plasticity to spread easily. If color is desired in the finish coat it can be obtained by adding mineral oxide pigment of the desired color according to the manufacturer's specifications. For light-colored finishes, white Portland cement should be used.

If stucco is being applied to a masonry wall, the surface of the wall should be dampened to insure that the scratch coat will bond well. The second coat should be applied not sooner than 24 hours after the first coat. The first coat should be scratched rather deeply to help provide a better bond for the second coat. This scratching can be seen in the illustration in (B) of Fig. 34. The second coat also is often scratched or at least finished with a rough wood trowel so as to provide a better bond for the final coat. The finish coat should not be put on sooner

than seven days after the second coat. Plaster coats should be kept constantly moist by sprinkling for at least two days as an aid to curing. Stucco work should not be attempted in cold weather.

Stucco can be applied in much the same way as a plasterer applies regular plaster to a wall. A steel trowel can be used for this work. Some experience is necessary and, if possible, a plasterer should be called in for the job, especially for walls having a great expanse.

There are a variety of textures possible for the finish coat. They are produced by smoothing or floating the surface with wood trowels or floats, sponges, and steel trowels. For example, a pleasing texture can be obtained by pressing a wet sponge firmly against the wood-troweled surface and then going over that texture lightly with a steel trowel. Other more complicated textures should be done by experienced masons or plasterers.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. Why the stability of a parapet must be assured?
Answer. Because of the danger to life and property should such a wall fail.

2. What the purpose is of coping?
Answer. It gives parapet walls a finished appearance and prevents water penetration of the joints of such walls.

3. What the maximum allowable projection is for wall corbeling?
Answer. Not more than one-half the thickness of the wall it is a part of.

4. What can be done to eliminate eccentric wall loads due to corbeling?
Answer. Pilasters can be constructed to help the wall support the load rather than requiring the wall to do it alone.

5. When the tooling of mortar joints may be done safely?
Answer. When the mortar has hardened sufficiently to hold its shape.

6. Why special care must be exercised when laying small masonry units?
Answer. Because the more joints there are, the greater the chances for variation in workmanship. This factor definitely affects the strength of a wall or partition.

7. How concave and V joints are made?
Answer. As walls are being laid up, the joints should be struck off flush with the surface of the units. When the mortar is practically set, the joints should be compressed and compacted with a pointing tool to form the desired joint.

8. In what kind of wall are all the bricks placed on edge?
Answer. The all-rolok wall.

9. Why the blocks making up the top course of a concrete block building wall are filled with concrete?
Answer. To provide a stronger bearing for the joists and rafters and to more evenly distribute the loads.

10. What kind of wall or wall panels an expansion strip is used in?
Answer. In glass block walls or panels.

11. Why it is necessary to carefully consider the lengths of masonry unit courses when planning walls?
Answer. To avoid cutting the units and thus spoiling the appearance of the exterior wall surfaces.

12. Why some walls and partitions are made thicker than structural requirements demand?
Answer. In order to house plumbing pipes, heating ducts, and other structural necessities.

13. What the maximum recommended depth is for chases?
Answer. They should not be deeper than one-third the thickness of the walls of which they are a part.

14. What the rise should be for segmental arches?
Answer. The rise should be equal to one inch for every foot of span.

15. How expansion stresses in masonry walls can be kept from causing cracks?
Answer. By having adequate bonding in the walls.

16. Why masonry units should be aged before using them in walls or partitions?
Answer. Because such units shrink between the time they are first made and when they are ready for use. If such shrinkage took place in a wall or partition, cracks would appear in them.

17. What mortar mix is recommended for most masonry work?
Answer. A 1:1:6 mix.

REVIEW QUESTIONS

1. If standard bricks are laid with $\frac{3}{8}''$ joints, how long will a course be if it is composed of 23 bricks?

2. What is the difference between a wall and a load-bearing partition?

3. Why is lateral support necessary for walls and partitions?

4. Where are parapet walls used or located?

5. What is meant by the expression "face shell bedding?"

6. What is a header? What is a stretcher?

7. What size chase is required for a 5" pipe?

8. What advantage have buttresses over pilasters?

9. Explain how to make joints watertight.

10. What are the factors which affect the strengths of masonry walls and partitions?

11. What type of mortar tends to produce the best bond between masonry units?

12. What mortar mix is recommended for face-shell bedding?

CHAPTER IX

Septic Tank Systems

QUESTIONS CHAPTER NINE WILL ANSWER FOR YOU

1. *Does a septic tank, in itself, render sewage completely harmless?*
2. *How should the tile lines in a purification field be laid when the soil is loose and contains a high amount of sand or gravel?*
3. *What is the depth recommended for septic tanks?*
4. *What precaution should be taken when pouring septic tank walls so as to obtain smooth, watertight concrete?*
5. *When are outside forms unnecessary for septic tank construction?*

INTRODUCTION TO CHAPTER IX

One of the more recent changes to be noted in rural localities is the disappearance from farm sites of the small building known as the privy. The privy is still to be seen but its place is rapidly being taken by the rural septic system. At a moderate cost, the modern farmer is able to obtain all the luxury of the toilet facilities of the city dweller. Because of the increasing use and popularity of these systems, the design and construction of septic tanks and their purification fields is discussed in this chapter.

If you make your home in a small town or live on a farm, the chances are you eventually will be called upon to build a concrete septic tank and lay its tile purification field. The construction of the tank and the laying of the tile pipe is no more difficult than some of the other aspects of masonry you have already encountered. The work must be planned and carried through to completion with care, however, for miscalculations or mistakes will prevent the system from functioning correctly and safely. It is obvious that a septic tank system is worse than useless if it does not function as intended.

In order to perform a creditable job in building such a system you will have to understand the principle of its operation. You must know how the forms are constructed for the tank as well as for the cover slabs. You must be able to visualize the layout for the purification field, selecting the best design to suit the needs of the family who will use it. You will have to know the correct proportions of aggregates, cement, and water in order to make a watertight concrete that will serve for years without leaking. You will have to understand the laying of the purification field tile under varying conditions of soil. And finally, you will have to know something of the care of septic tanks and precautions to be observed when working around them. Lack of oxygen within the tank, presence of highly inflammable gases, or presence of noxious gases are some of the dangers that may be encountered.

A careful study of this chapter will prepare you for this job.

THEORY OF SEPTIC TANK SYSTEMS

A septic tank system is a device or means employed to provide safe and inoffensive disposal of sewage from water closets and wash basins or sinks in a residence and, as on a farm, to help protect the water supply against pollution. Unless sewage is properly taken care of and made harmless, it can cause severe illness both to people and farm animals. Therefore, in rural communities or on those farms where residences are piped for running water but have no standard sewers available, the septic tank system is recommended as a safe and sure means of proper sewage disposal.

Fig. 1 shows a rough sketch of a typical layout for a septic system. The soil pipe in the residence is connected to the house sewer which in
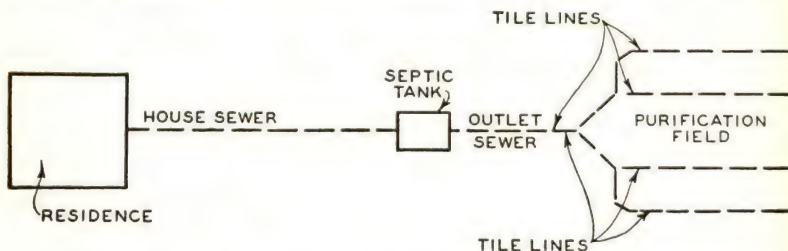
Fig. 1. Standard Layout for Septic Tank Systems

turn is connected to the septic tank. From the septic tank the outlet sewer extends to the purification field.

For the house and outlet sewers, bell-mouthed concrete or glazed clay tile are used and their joints tightly cemented. This is insurance against any sewage escaping into the ground near the residence or water supply. For the purification field tile lines, concrete or clay tile without bell mouths are used, laid so there is a little space at each joint. The septic tank is constructed of poured-in-place concrete.

How a Septic Tank System Functions. The sewage from water closets and wash basins or sinks flows into the residence soil pipe and then into the house sewer. From the house sewer the sewage flows to the septic tank where the first process of rendering sewage harmless takes place. Care should be taken to see that no grease, oil, acid, or gasoline in any appreciable quantity is emptied into any of the residence drains since such wastes tend to hinder the process in the septic tank which helps
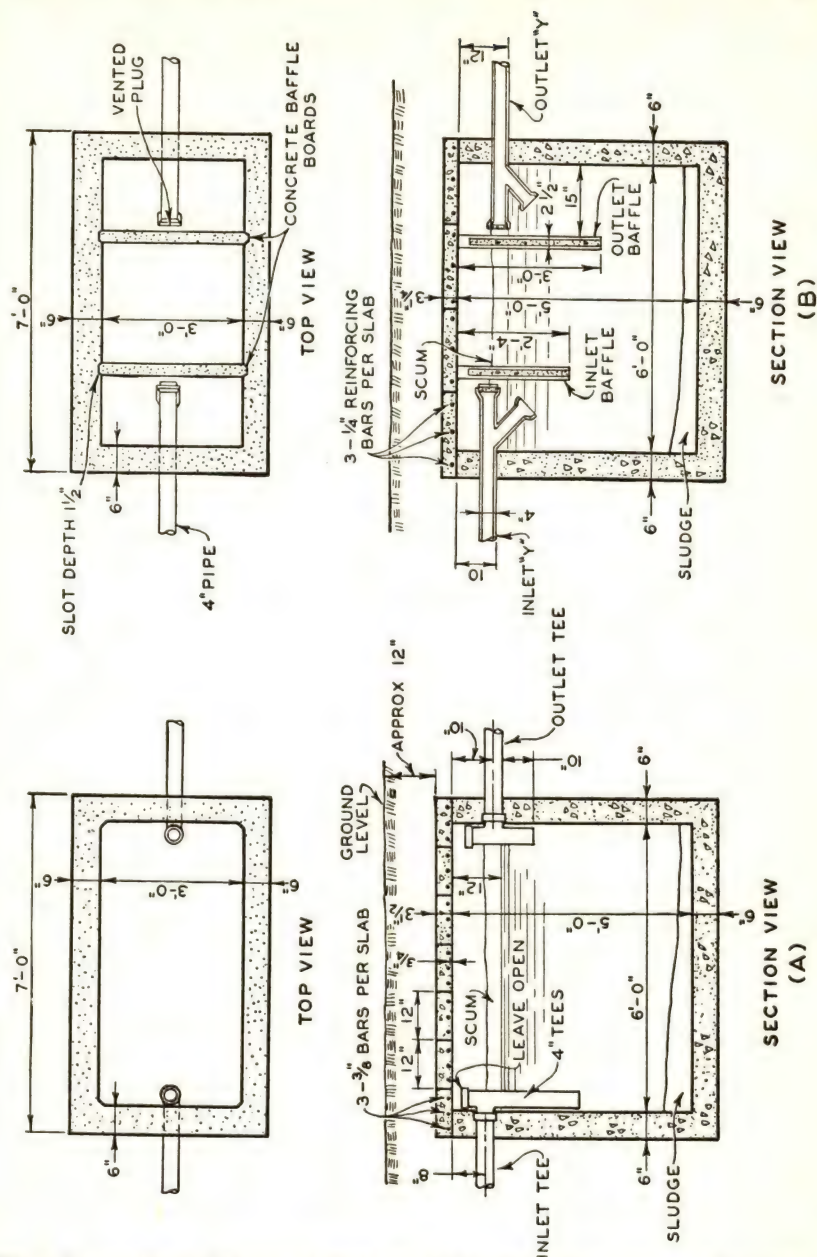
Fig. 2. Top and Section Views of a Septic Tank for a Small Family, (A), and Top and Section Views of a Septic Tank Equipped with Baffles Which Retard the Flow of Sewage, (B)

render sewage harmless. Rain water from roofs should not be drained into the house sewer because such water does not need purification and because too much water also tends to retard or destroy the process by which the septic tank helps reduce the sewage to a harmless state.

The chemical action or process which takes place within a septic tank is not explained in this discussion because it is of no importance or interest so far as the actual design, construction, and laying of a septic tank system is concerned. For the purposes of this discussion it is sufficient to know that parts of the processed sewage (sludge) must be removed from the septic tank periodically while the remaining material, a water-like fluid, is disposed of by means of the purification field. The sludge must be buried in the ground.

The processed, water-like fluid from the septic tank drains through the outlet sewer to the purification field where it is distributed to the various tile lines. As the fluid runs through the tile lines it gradually escapes through the open joints and is absorbed by the surrounding soil. By this process the fluid is distributed over a large area. Since the tile lines are near the surface of the soil, the sunshine, oxygen, and bacteria purify it.

KINDS AND SIZES OF SEPTIC TANKS

In (A) and (B) of Fig. 2 are illustrated two typical kinds of septic tanks. It should be noted that these tanks do not vary much in design or size. The tank shown in (A) is a small family tank, whereas the tank pictured at (B) is for a larger family. The chief differences in tanks for large and small families is the use of baffle boards which is a means of retarding the larger flow of sewage which would naturally result from a larger family. In both tanks shown in Fig. 2, the house sewer is connected to the inlet tee or **Y** and the outlet sewer is connected to the outlet tee or **Y**.

Septic tanks of somewhat different shapes and kinds than those shown in Fig. 2 frequently are built but there is little or no difference in their operation or value except that a rectangularly shaped tank seems to function better than a square one. A standard, poured-in-place concrete tank is shown in Fig. 3.

There is not much exact or definite information available for use in determining the proper size for a septic tank. Most authorities on

Fig. 3. Interior View of Poured-in-Place Concrete
Septic Tank Showing Baffle Slides and Outlet **Y**
Courtesy of Portland Cement Association

sanitation agree, however, that the minimum interior size for a tank serving a family of from three to six people should be no less than 2′6″ wide, 6′0″ long, and 5′0″ deep. This tank has a capacity of 75 cubic feet and is adequate to serve the needs of such a family. A septic tank of smaller capacity is impractical because some leeway must be allowed for the storage of the sludge (see Fig. 2.) which will gradually accumulate. A tank of larger size is inadvisable because the important purification activity is retarded.

Where residence installations must be provided to serve a larger number of people, it is an accepted practice to allow as little as 6 cubic feet of tank content per person. The size of the septic tank is increased slightly as shown in (A) and (B) of Fig. 2.

It should be remembered that septic tanks of larger capacity do not function as well as those described. In addition, overloading of the system causes too fast a flow through the tank to give the best results.

DESIGN OF SEPTIC TANK SYSTEMS

There are many items to be considered in the design of a septic tank system, each one of which is equally important so far as the proper functioning of the system is concerned. Each of these items must be given careful consideration since the failure of a single unit will render the complete system useless, or troublesome and undependable at best.

Location of a Septic Tank System. It has been pointed out that the purpose of a septic tank system is to dispose of sewage while protecting the water supply. Both of these points are important but the protection

of the water supply is considered first since much of the sewage is disposed of through the purification field. Thus, the treated sewage finds its way into the same soil from which comes the water supply. If the water supply did not have to be considered, the septic tank system could be placed in almost any convenient place.

The purification field for a septic tank system should be from 100′ to 200′ away from the well or other water supply. The house sewer, septic tank, and outlet sewer can, if necessary, be much closer to the water supply because they are all supposedly leakproof in construction. However, the possibility of a leak is always present so the best policy is to have those parts of the system also at least 100′ to 200′ away from the water supply. The reason for this location specification is that sewage is able to seep through soil a great distance. If the water supply is too close, some of the sewage might enter it and cause serious illness to men or animals drinking the water.

Slope of System. The flow of sewage through an entire septic tank system is by gravity. Therefore, there must be a continual slope or pitch to the house and outlet sewers as well as to all tile lines in the purification field. This means that the ground area where such a system is to be constructed and laid should have a definite slope away from the residence being served. If the ground area is sloping toward the residence, the construction of a septic tank system is impossible. If the ground area is nearly flat, the house sewer must be connected to the residence soil pipe as near the surface of the ground as possible.

Fig. 4 shows a typical septic tank system. Note that the slope of the ground area, in which the system is constructed and laid, has only a slight slope away from the residence. Note also that the house sewer is connected to the residence soil pipe just below the first floor level in order to allow proper slope in the system. If the ground slope were more pronounced so that the purification field were lower than the basement floor level, the connection between the soil pipe and the house sewer could be underneath the basement floor. However, the top of the septic tank should not be more than 12″ below ground level to avoid excess trouble at cleaning times.

The slope of any particular ground area for which a septic tank system is contemplated is studied most accurately by means of a surveyor's level. If there are any doubts as to a sufficient degree of slope,
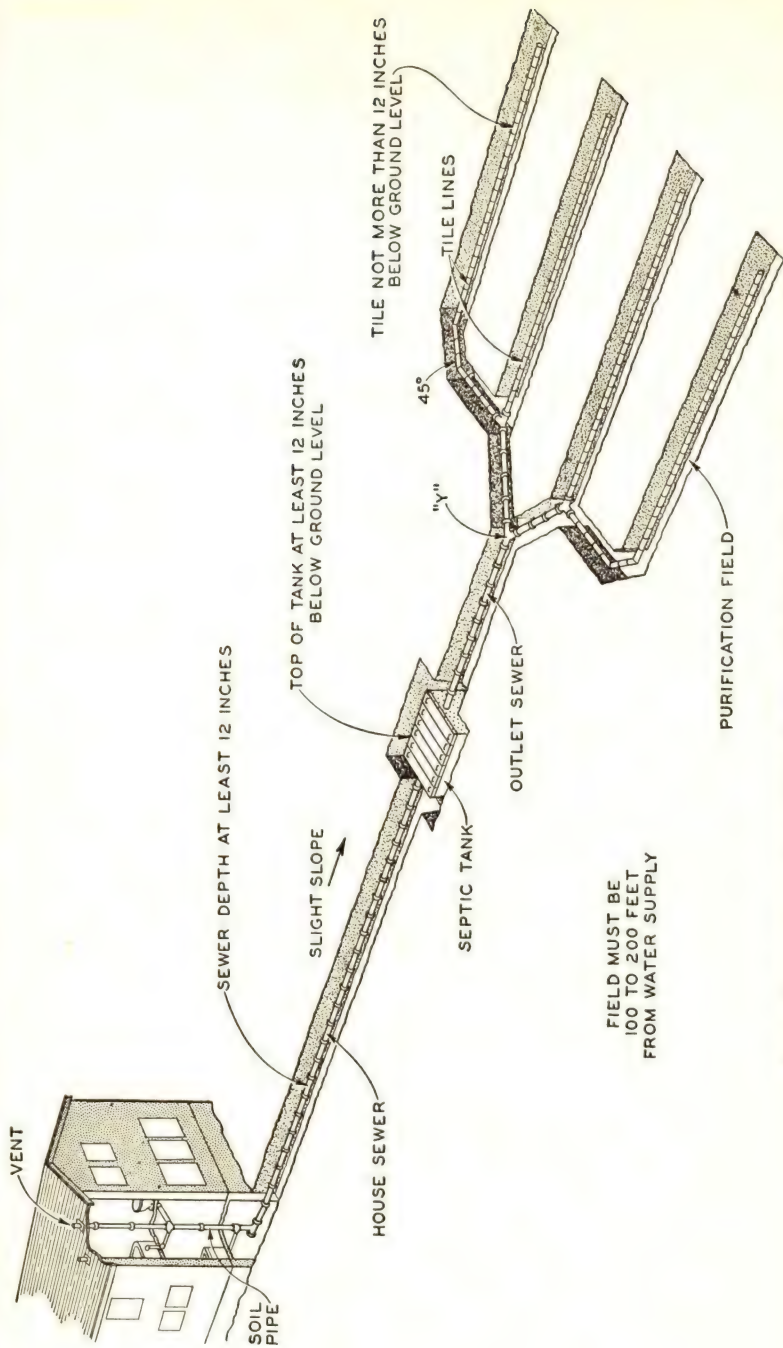
Fig. 4. Typical Septic Tank System Showing the Various Parts to the Best Advantage

a county or city surveyor should be consulted with the following requirements in mind.

SEWER AND TILE LINE SLOPES. The house and outlet sewers should have a slope of at least 1″ to every 5′ of length. This is the minimum slope for good gravity flow. The tile lines in the purification field should have a slope of at least 1″ in every 25′ so that a slow but certain flow will take place, allowing some of the water-like fluid to escape through the loosely laid joints. The septic tank should be perfectly level.

Tile for Sewers and Purification Field. The house and outlet sewers are laid using either 4″ or 6″ bell-mouthed concrete or glazed tile pipe. The tile lines in the purification field should be of 4″ clay tile pipe without the bell mouths. It will be noted in Fig. 4 that **Y** and 45 ° tile angle fittings are required in the purification field tile lines. This system is ideal since there are no turns or twists in the house or outlet sewers. Even a 45° turn in a sewer line tends to reduce or retard the flow. To slow up the flow in a system having no more than the minimum allowable slope eventually might cause the sewer to clog. If changes in direction are necessary, long-turn fittings should be employed.

Purification Field Layout. The layout of a purification field depends, first, on the number of people served by the system and, second, on the ground area which is available.

In loose soils containing large proportions of sand and gravel and where the level of the ground water is several feet below the surface, a purification field can be planned using as little as 30 lineal feet of tile line per person in the residence being served. In tight or solid soils as much as 100 lineal feet of tile line must be provided per person. The safest plan is to provide more lineal feet of tile line than seems necessary and complete purification and disposal will take place without trouble.

The layout of the purification field in Fig. 4 is typical and one that is recommended. It is economical and one that is easily laid. In (A) and (B) of Fig. 5 are shown two other plans for the tile lines in purification fields. Both are excellent. The plan in (A) can be used for large families or where the ground that is available does not permit long runs. The plant in (B) can be used for small families or where long runs are possible. Distribution boxes, as the name implies, serve to distribute

more efficiently the flow of treated sewage into the various tile lines and are recommended especially for the service of large families with the resultant greater flow of sewage.

VENTILATION. During the process whereby the sewage is rendered harmless, gases of various kinds are formed. Ordinarily, the gases would escape harmlessly through the vent forming the top of the residence soil pipe (see Fig. 4) or would find their way into the purification field to be disposed of there without any danger. However, if by
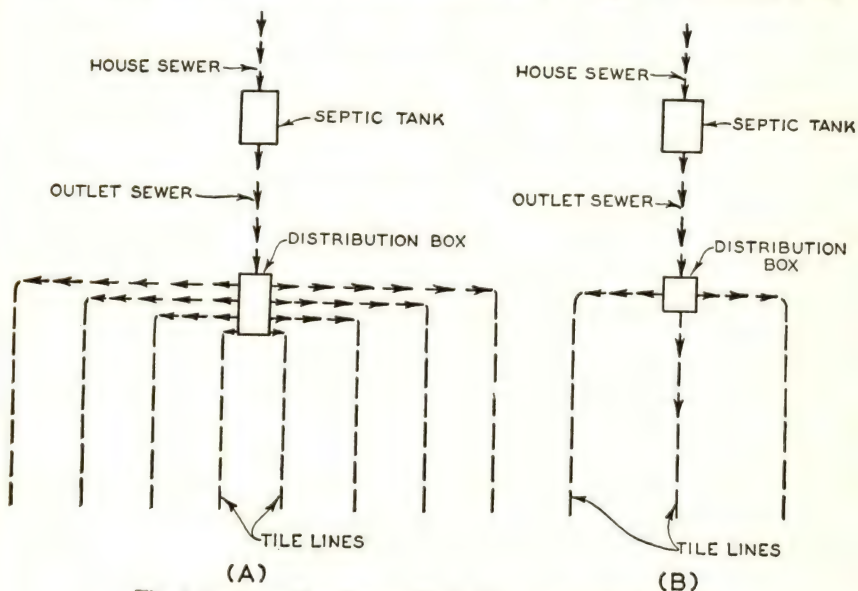
Fig. 5. Layout of Purification Fields Using Distribution Boxes

any chance such gases are not satisfactorily vented with the result that their odor can be detected in the residence, a vent pipe should be constructed from the septic tank to the air above ground. A system such as shown in Fig. 4 usually functions properly without the need of any vent other than the one forming part of the residence soil pipe.

CONSTRUCTION OF A SEPTIC TANK SYSTEM

After the design of a septic tank system has been decided upon and the locations of the various components planned, the actual construction and laying of the system can proceed.

Excavating for a Septic Tank. Suppose the excavation must be made
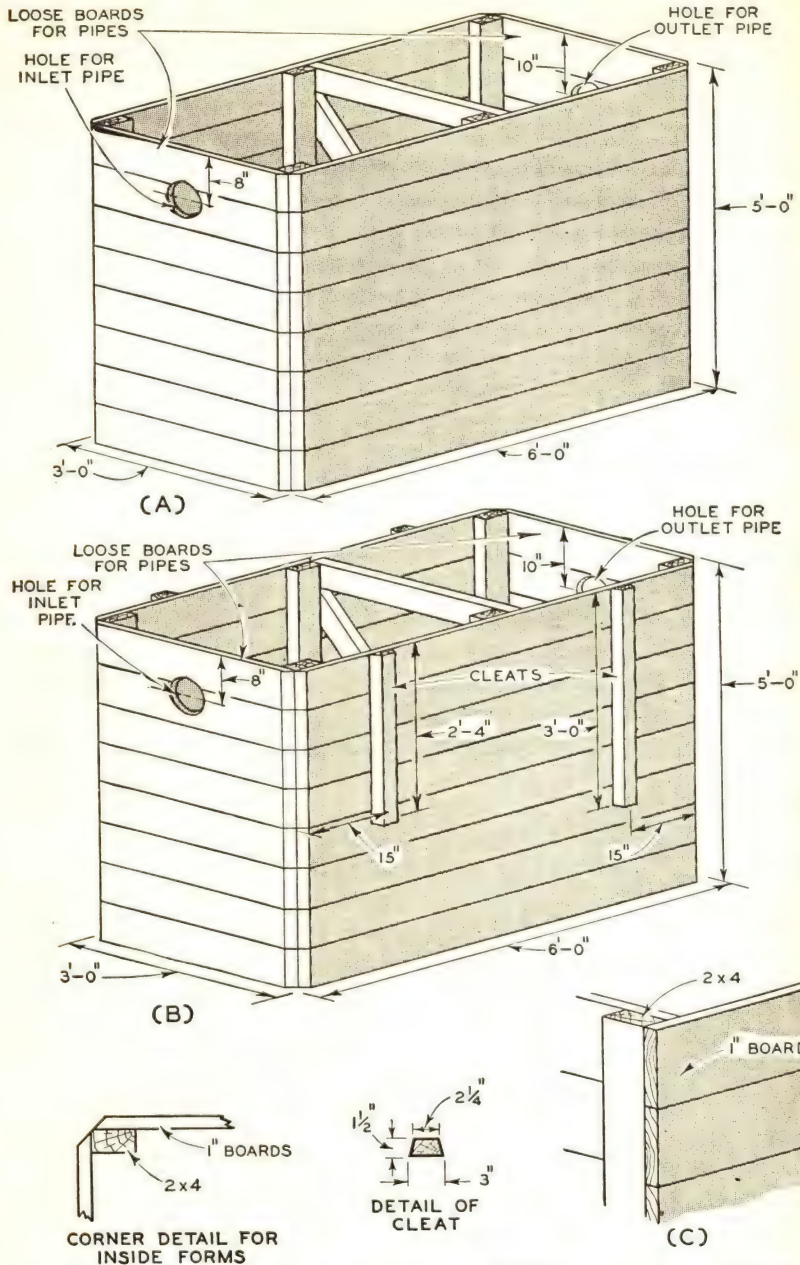
Fig. 6. Inside Forms for Septic Tanks (A) and (B) Respectively in Fig. 2 and Construction Details, (C), for Making Outside Forms for Septic Tanks

for either of the tanks shown in Fig. 2. Adding the tank floor thickness of 6″, the inside depth of 5′0″, the top thickness of 3½″, and the depth below the ground level of 12″, the exact depth required for the excavation must be at least 6′9½″. The dimensions for the width and length are obtained in a similar manner.

The pit can be dug to the exact dimensions and the sides of the excavation used as outside forms when pouring the concrete, provided the soil is firm and will not cave in. Where this is possible, care should be taken to see that the sides of the pit are smooth and vertical and that the corners are square. If the soil is not firm enough to be safe against caving, the pit must be excavated sufficiently wide and long to allow the placing and securing of outside forms.

Forms for Septic Tank Walls. Assuming the earthen walls of the pit can be used as the outside forms, it is necessary to construct only the inside forms such as shown in (A) and (B) of Fig. 6. These are the forms for the septic tanks shown in Figs. 2 and 3. Note how the two boards at each end of the forms must be loose in order that the tees or **Y**'s can be put in place while the concrete is being poured.

The tank shown in (B) of Fig. 2 has baffles. Therefore, beveled cleats must be nailed to its inside form (shown in Fig. 7) so as to provide the slots which hold the baffles in place. The completed slots can be seen in Fig. 3 which shows the tank after the pouring has been completed and the forms removed.

The forms are constructed using 2 x 4's and ¾″, ⅝″, or 1″ boards. The forms are simple to make. Any difficulties should be cleared up easily by referring to (A) and (B) of Fig. 6. If

Fig. 7. Forms in Place for the Pouring of a Concrete Septic Tank
Courtesy of Portland Cement Association

outside forms are required, they are constructed as indicated in (C) of Fig. 6, using the same size lumber as for the inside forms. Separators and wire must be used in building these forms just as was done in building foundation forms.

The floors and walls of septic tanks must be integral; that is, all one piece. To accomplish this, the forms are hung or supported so that they are 6″ above the floor of the pit.

Fig. 7 is a view showing the forms in place and ready for the pouring of the concrete. Note the use of planks around the edge of the excavation. Their purpose is to prevent the caving in of the earth walls which in this case are serving as the outside forms. If the sides of all forms that face the concrete are oiled, their removal when the concrete has hardened will be much easier.

Mixing and Pouring Concrete for Septic Tank Walls. A 1:2¼:3 mix in which the maximum aggregate size is 1½″ is recommended for septic tank construction. If the sand is damp, wet, or very wet, 5¼, 5, or 4½ gallons of water should be used respectively per bag of cement. A trial mix should be made first, either by hand or using the mixer. If the mix is too wet, a little more sand, gravel, or pebbles should be added, a little at a time, until the mix is smooth and easily worked. If the mix is too stiff, omit some of the sand, gravel, or pebbles. *Do not add more or less water.* The amounts of materials to make the concrete needed for the tank shown in Fig. 2 are estimated at 2 cubic yards of sand, 2¼ cubic yards of gravel or pebbles, and 17 sacks of cement.

The concrete for the floor of the tank is placed first by dumping a sufficient quantity to cover the bottom of the pit to a depth of 6 inches. The corners should be carefully spaded so as to remove all voids. As soon as the required 6″ of floor concrete has been poured, the concrete for the walls is poured.

In pouring the concrete for the walls, care should be taken not to dump too much concrete at one place. The best practice is to distribute each batch of concrete all around the forms in 6″ to 8″ layers. After each batch is placed, the concrete should be spaded carefully and thoroughly next to the forms in order to make a dense, watertight wall.

The inlet and outlet **Y**'s or tees must be placed as the concrete is put into the forms. Once they are in place, the loose boards may be nailed fast if so desired.

The tops of the walls should be finished so that they are smooth and true. This is necessary in order that the top slab sections will sit evenly and tight.

During warm weather the forms should not be removed until at least two days have passed since the concrete was poured. In cold weather the forms should not be removed for at least a week. The concrete should be allowed at least three weeks' time to harden before the tank is put into service. During very cold weather at least five weeks' time should be allowed for this curing.
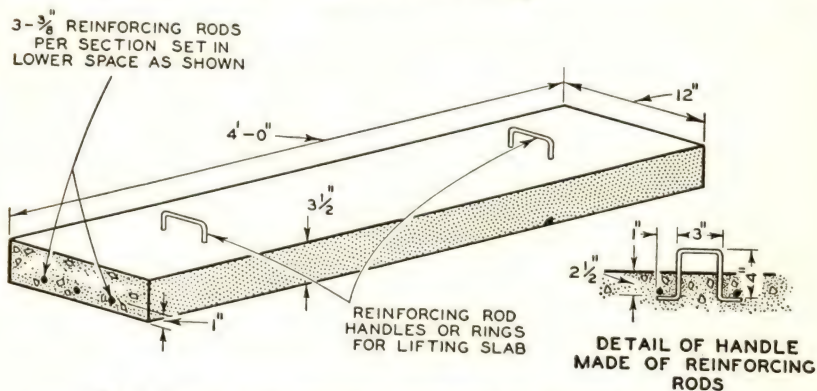
Fig. 8. Detail of One Section of Cover Slab for Concrete Septic Tank

Forms for Septic Tank Cover Slabs. As shown in Figs. 2 and 8, the cover slabs for concrete septic tanks are also made of concrete and are in the form of several individual sections. For the tanks shown in Fig. 2, the slab is composed of seven sections, each of which is 4'0" long, 1'0" wide, and 3½" thick. These individual slabs are easily removed at cleaning times. Note that each section is provided with two handles which can be made from reinforcing bars or old horseshoes.

The forms for the slab sections can be made similar to those shown in Fig. 8. The form pieces may be 2 x 4's. As shown in Fig. 9, the forms should be placed on a wooden platform so that the bottoms of the slab sections will be smooth and square.

The forms for the baffles are made in much the same manner as just described for the slab sections.

Pouring Concrete for Slab Sections. The same mix concrete is used for the slab sections as was used in the walls of the tank. The mix

should be made a little stiff rather than wet. This can be accomplished by adding a little more gravel and sand when making the mix.

About ¾″ to 1″ of concrete should be placed in each section. Three reinforcing bars per section are then laid in place as shown in Fig. 8. The remainder of the concrete is then poured directly over the bars until the required thickness has been reached. When the concrete has set sufficiently the surface is troweled so as to provide a smooth finish.

During warm weather the forms can be removed on the third day after pouring. The sections should not be used for at least three weeks
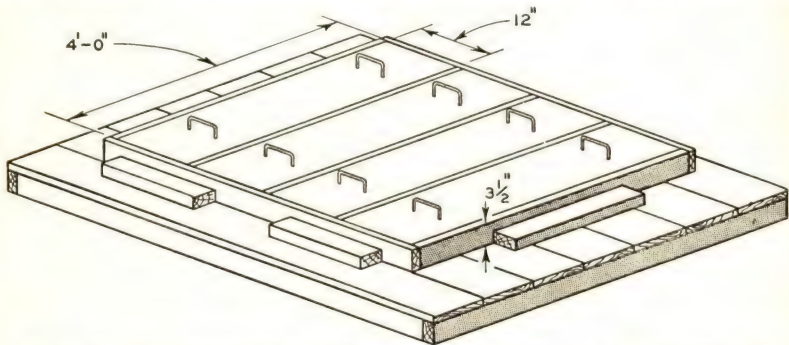
Fig. 9. Forms for Making Reinforced Concrete Slab Sections for Septic Tank Cover

after they have been poured. The pouring for the baffles is just the same as for the slabs except that no reinforcing bars are needed.

Excavating for and Laying House Sewer. The depth of the excavation for the house sewer will depend on the slope of the ground. Once this has been determined, a 12″ trench is dug to the correct depth. Care should be used to maintain the minimum drop of 1″ every 5′ of pipe laid. If the ground slopes 1″ or more every 5′, it is only necessary to maintain an even depth to be sure of having a trench of the required slope. If there is no slope or if it is insufficient, the trench will have to be made gradually deeper.

As the sewer tile is laid, the joints should be made as tight and as close as possible. Each joint should be carefully cemented all the way around with a mortar composed of one part cement and three parts sand. This mortar should be forced well into the joints and the outside surface smoothed off. A day's time should be allowed for the mortar to harden before the trench is backfilled. When backfilling, care should be

taken to tamp the earth around the tile so that it will be held firmly in the correct position.

The outlet portion of the sewer is laid following the same procedure as outlined for the house sewer.

Provisions for Tile Lines in Purification Fields. In (A) of Fig. 10 is shown a section view of the tile line trench for a purification field which has been excavated in loose earth. The looseness of the earth is depended upon to quickly absorb the sewage from the tile lines. The trenches are made somewhat larger and are partly backfilled with gravel, crushed stone, or cinders when the soil is firm or tight. These
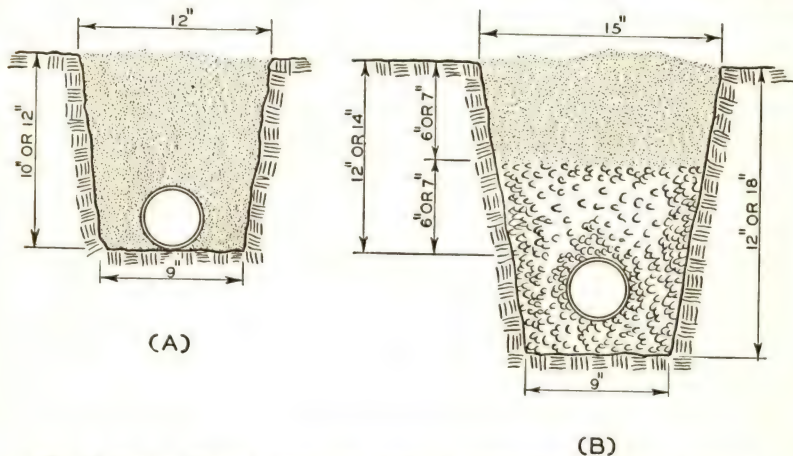
Fig. 10. Section View of a Tile Line Trench in Loose Earth, (A), and in Firm or Tight Soils (B)

loose materials provide a space where the sewage from the tile lines is held while it is slowly absorbed by the soil. Such a trench is illustrated in (B) of Fig. 10. These tile lines should never be more than 12" to 18" below the surface of the ground.

TILE AND DISTRIBUTION BOXES

Various grades, kinds, and sizes of tile and various tile fittings such as elbows, tees, **Y**'s, 45's, etc., can be purchased from lumber yards throughout the country. Distribution boxes also are obtainable at lumber yards although they are not as common as the tile. If the boxes are not carried in stock it may be necessary in some cases to lay out

the purification fields in the manner shown in Figs. 1 and 4. It is well to inquire about them prior to planning the layout for a purification field.

CARE OF SEPTIC TANKS

Septic tanks require very little attention if they have been built carefully and are large enough for the number of people in the residence being served. It is good practice, however, to examine the tank once every three years, removing all the accumulated sludge so that the tile lines will not become clogged. When sludge is removed it should be immediately buried in the ground at least 24″ deep. The sludge has no significant fertilizing value and therefore should not be used for such purposes. Disinfectants should never be used in the septic tank because such materials destroy the bacterial life which is the chief agent responsible for the decomposition of the sewage.

PRECAUTIONS

Extreme care should be exercised when removing sludge because the tank may contain dangerous poisonous gases. When removing sludge or repairing a tank, the cover slab sections should be removed and the tank allowed to air out at least half a day in advance of the sludge removal or repair operations. When the cover is first removed from the tank, some of the escaping gases may be highly inflammable. For this reason, all forms of fire should be kept well away from the tank.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind.

DO YOU KNOW

1. What part of a septic tank system other than the tank itself helps render sewage harmless?

Answer. The purification field where the water-like liquid draining away from the septic tank is purified by the sun and bacteria which occur near the surface of the ground.

2. If bell-mouthed tile are used for the tile lines in the purification field? Why?

Answer. The tile in the purification field lines are not of the bell-mouth variety and are purposely laid with their ends somewhat apart so as to allow the water-like septic tank fluid to escape into the soil.

3. If it is good practice to allow rain water to drain from a roof into a septic tank? Why?

Answer. So much water flowing into a septic tank tends to retard or destroy the process by which the septic tank renders sewage harmless.

4. How many reinforcing rods should be put into each section of the top slab of a septic tank?

Answer. Three.

5. What the purpose is of baffles in septic tanks?

Answer. They retard the incoming flow of sewage.

6. What type tile should be used for the house sewer? Why?

Answer. Either concrete or glazed tile having bell-mouthed joints should be used because each joint must be cemented watertight.

7. What the function is of distribution boxes for purification field tile lines?

Answer. They insure a more even flow of the waterlike fluid into all tile lines.

8. Why small septic tanks are impractical?

Answer. Because they do not allow much leeway for the storage of sludge.

9. Why the slope of the house and outlet sewers and the purification field tile lines is important?

Answer. Because the action of the entire septic tank system depends on gravity flow.

10. Why turns or twists in septic tank sewer lines are to be avoided.

Answer. Because every change in direction in a sewer line tends to slow the flow of sewage or to allow solids in the sewage to collect near the change-of-direction points.

11. How to determine the lineal feet of tile necessary for a purification field in loose soil.

Answer. In loose soil there should be at least 30 lineal feet of tile per person served by the septic tank system.

REVIEW QUESTIONS

1. Explain how the waterlike fluid flowing from a septic tank gets into the soil in the purification field.

2. Why must the tile lines of a purification field be near the surface of the ground?

3. If the tile lines of a purification field had to be laid in firm or tight soil, what should be done to increase absorption?

4. Is it wise to allow grease or oils to get into septic tanks? Why?

5. How frequently should septic tanks be cleaned?

6. When cleaning septic tanks, what precautions should be observed?

7. What shape of septic tank seems to be the best?

8. Are the reinforcing rods in septic tank top-slab sections placed near the top or near the bottom of each section?

9. Is it necessary to use reinforcing rods in the baffles?

10. Is it necessary to use baffles in a septic tank serving two or three people? Why?

11. How far from the well or water supply should the purification field of a septic tank system be?

CHAPTER X

Building with SCR* Brick

QUESTIONS CHAPTER X WILL ANSWER FOR YOU

1. *How high may walls be constructed from one wythe of brick 6" wide?*
2. *How are furring strips fastened to an SCR brick wall?*
3. *How are door and window frames secured in an SCR brick wall?*
4. *What means are used to anchor head plates to an SCR brick wall?*
5. *What are three common methods for constructing lintels over doors and windows when building with SCR brick?*

INTRODUCTION TO CHAPTER X

Most single-family homes being erected today have only one-story load-bearing exterior walls. Because of the sizes of standard brick, such houses are ordinarily built with 8" walls. A wall of that thickness possesses sufficient strength for a three-story structure and is unnecessarily heavy for a dwelling of one story. This is emphasized by the fact that all major national building codes approve 6" masonry walls for one-story residences.

Many local building codes have long recognized the adequacy of 6" masonry walls for one-story buildings. With the increasing popularity of this type of construction, additional local codes have extended their approval. A variety of 6" clay building products have appeared for use in one-story residential and industrial buildings. Some of these are hollow units classed as tile, whereas others are considered as solid units, or brick. In this chapter, we shall treat in some detail a representative example, the SCR brick. The data presented can be regarded as fundamental and applicable to the use of similar products.

The SCR brick was developed by the Structural Clay Products Research Foundation. It was designed as a through-the-wall unit requiring no backup material; with it, a nominal 6" wall can be constructed with a single wythe. The SCR brick is intended to adapt masonry construction to present housing design trends at a cost that can compete favorably with other building materials.

DESCRIPTION

As can be seen in Fig. 1, the SCR brick is conventional in appearance; it presents a face outline like that of the standard Norman brick. Its actual dimensions are $2\frac{1}{6}$" x $5\frac{1}{2}$" x $11\frac{1}{2}$ inches. When the $\frac{1}{2}$"

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* Reg. TM "SCPRF"—Pats. Pdg.

allowance for joints is added, the brick has, for construction purposes, a nominal size of 2⅔″ x 6″ x 12 inches. Its weight, when it is of usual composition, is about eight pounds. The unit has ten vertical holes, each 1⅜″ in diameter. The holes constitute less than 25 per cent of the total volume, so the brick is regarded as a solid masonry unit. In one end of each brick, a ¾″ x ¾″ jamb slot is provided to facilitate construction around openings.
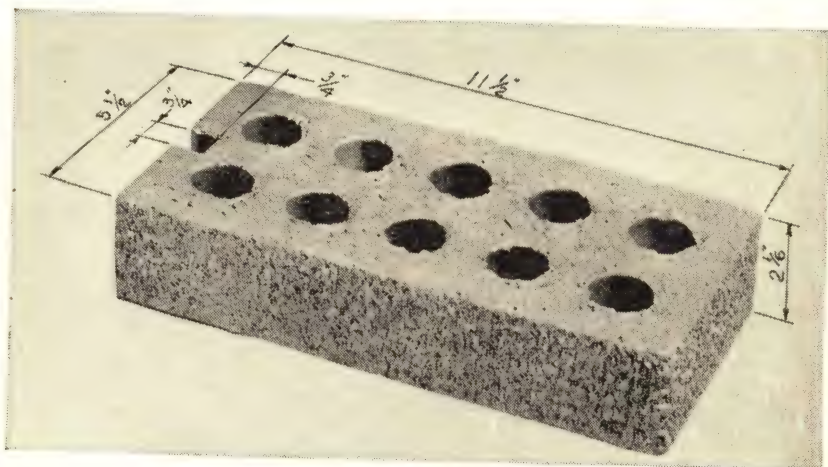
Fig. 1. The SCR Brick
Courtesy of Structural Clay Products Institute

PHYSICAL PROPERTIES

Except in size, the SCR brick does not differ from ordinary brick. It is made from the same materials, and by the same processes employed in manufacturing conventional units. The choice of colors will be the same as for standard brick produced by the manufacturer. Single-wythe walls of SCR brick have been subjected to the customary laboratory tests with satisfactory results. These included tests for strength, fire resistance, and moisture penetration.

ACCEPTANCE

All nationally recognized building codes permit the use of 6″ masonry for exterior load-bearing walls of one-story single-family homes and private garages. The wall height must not exceed 9′ to the eaves or

15′ to the peak of the gables. The same specifications meet the standards of the Federal Housing Administration (FHA). Use of such brick has been endorsed by the Bricklayers, Masons and Plasterers International Union (AFL).

Fig. 2. Brickmason Laying SCR Brick
Courtesy of Structural Clay Products Institute

LAYING THE SCR BRICK

Working with SCR brick does not present any particular problems. The mason may span the entire unit with the hand, as demonstrated in Fig. 2, or, for easier handling, the core holes provide a convenient hold. These same holes help to reduce "floating" of the brick on very wet or plastic mortar. Tests have disclosed that where the maximum transverse strength is desired, mortar Type A-2 $(1:\frac{1}{2}:4\frac{1}{2})$ is to be preferred.

SCR brick must be laid with completely full mortar joints to insure maximum strength and weatherproofing.

The SCR brick is a modular unit, that is, its dimensions can be taken as a unit of measurement in laying out work. It is most easily used with a stretcher (half) running bond, as shown in Fig. 3. Walls and corners can then be laid using only whole brick. If door and window
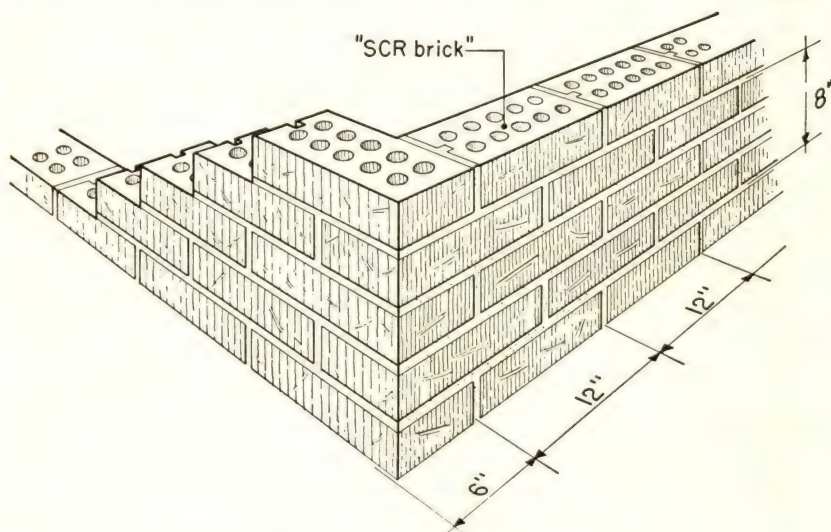
Fig. 3. Simple Wall Construction with SCR Brick
Courtesy of Structural Clay Products Institute

widths and wall lengths are planned in multiples of 6″ or 12″, only half-units will be required to work around the openings with no attendant waste of material. Three courses of SCR brick make 8″ of wall height; and 450 units are needed for 100 square feet of wall area.

CONSTRUCTION DETAILS

Wall Construction. A 2″ x 2″ furring strip is recommended for use with SCR brick wall construction. Such furring provision allows ample space for a moisture barrier, and installation of electrical and plumbing equipment, as well as insulation. The 2″ x 2″ stock offers sufficient rigidity to permit anchoring the strips only at three points. Since the strips can be nailed to the top wall plate, only two clips will be required. The special clip shown in Fig. 4 has been devised for use with this con-

struction arrangement. The furring strips are driven onto the staples after the wall is completed. The width of the clip allows the horizontal positions of the staples to be adjusted as needed to align them properly. The clips hold the furring approximately ¼" away from the masonry; this feature allows air to circulate freely and permits moisture readily
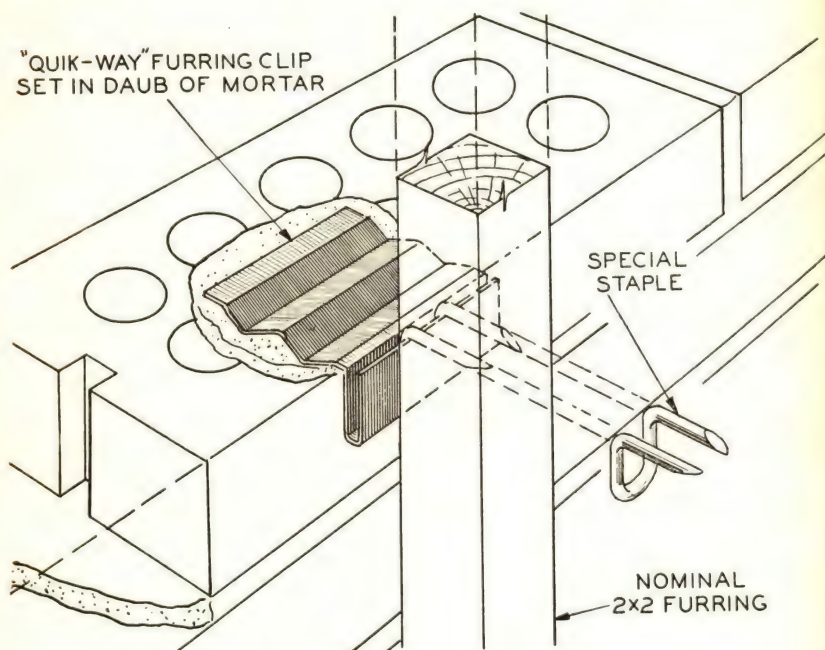
Fig. 4. Furring Clip Designed for Use with SCR Brick Construction
Courtesy of Structural Clay Products Institute

to drain down to the weep holes in the bottom course, as can be seen in Figs. 7 and 8.

The space provided by the furring can be insulated in the same manner as in any wall. The cavity is adequate to carry most standard electrical installations and piping. It must be observed, however, that pipes or ducts cannot be cut into single-wythe SCR brick walls. Building codes do not permit reducing the nominal thickness of a 6" wall. Where pipes or ducts cannot be run through the furred-out space, they must be boxed in. For heating systems, special "out-of-wall" and baseboard registers are available.

All lath for plastering and all wallboard is made in multiples of 16″, so when clips for fastening furring strips are placed in the masonry they should be laid out to conform to the 16″ O.C. that is standard in frame construction, as shown in Figs. 5 and 6. Thus waste of lath or
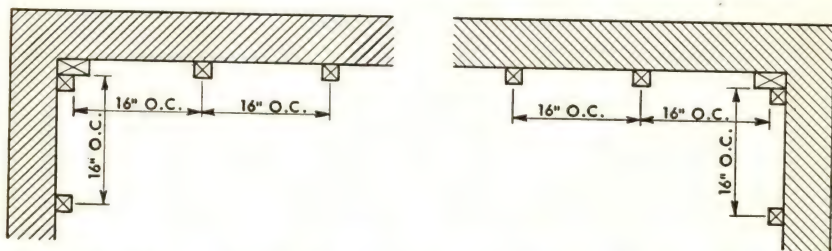
Fig. 5. Typical Interior Corner Furring of SCR Brick Using a 2″ x 4″ and a 2″ x 2″. The Center of the First Furring Strip Away from the Corner in *One* Direction Should Be 16″ Plus the Thickness of the Lath or Wallboard to Be Used

other interior materials is avoided. The spacing of furring at 16″ centers must be done according to interior dimensions and, of course, maintained from bottom to top of the wall.

All standard blanket insulation is also made for installation between nominal 2″ framing spaced 16″ O.C. Proper spacing of the fur-
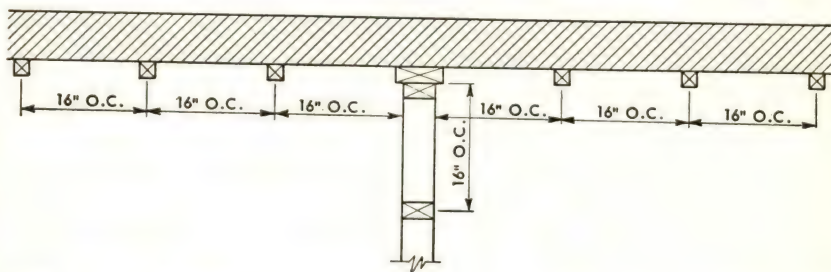
Fig. 6. Typical Furring Method Used Where Interior Partitions Meet Exterior Walls of SCR Brick Using a 2″ x 6″ Centered on the Partition Using 2″ x 4″ Studding. The Center of the Second Stud in the Partition *Or* the Centers of the First Furring Strips Away from the Angle Should Be 16″ Plus the Thickness of the Lath or Wallboard to Be Used

ring will avoid waste of the insulation material, make installation easier and so lower the cost while improving the efficiency of the insulation.

Foundations. Laying SCR brick on a standard 8″ foundation requires no special instructions. With slab-on-the-ground building where

no basement is to be provided, the wall is very simply erected on the foundation as shown in Fig. 7. In cold climates a rigid mineral insulation should be installed between the floor construction and the exterior foundation wall.

Floor joists cannot be framed into a 6″ masonry wall. If a basement or crawl-space is planned, metal hangers must be installed or the wall must be corbeled out to provide a bearing surface for the joists. The
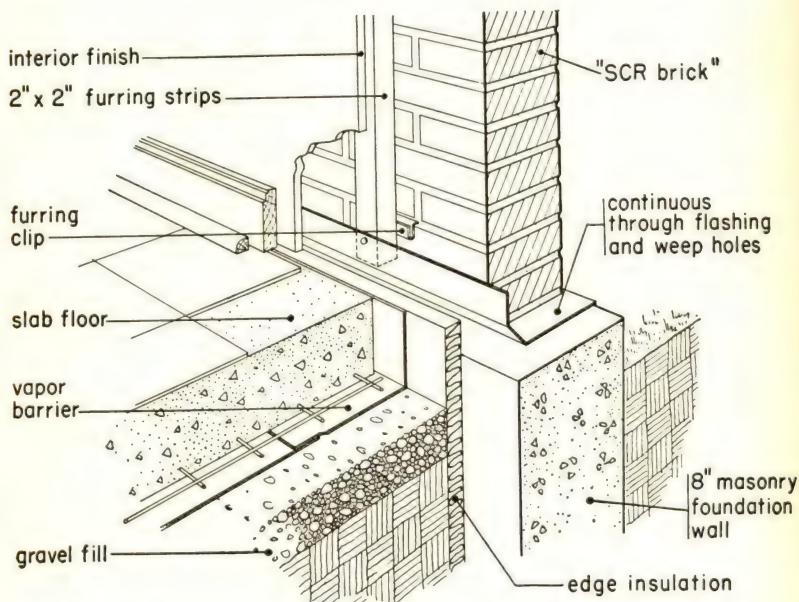
Fig. 7. Foundation Details with Slab-on-the-Ground Construction
Courtesy of Structural Clay Products Institute

latter arrangement is preferable and one method of doing this is illustrated in Fig. 8. It should be noticed that in all cases the furring strips extend only to within 2″ or 3″ of the floor level. This allows for a gradual curve of the metal flashing to improve drainage to the weep holes.

Because of unusual local conditions in some areas, building regulations may require 10″ or 12″ foundation walls. Simple methods have been worked out to accommodate the SCR brick to such foundations. Fig. 9 shows how the wall can be erected on a 10″ foundation. In this

interior finish over 2"x 2" furring strips

"SCR brick"

continuous through flashing and weep holes

wood joist floor construction

clipped "SCR brick"

standard brick

corbel to provide 4" joist bearing

8" masonry foundation wall
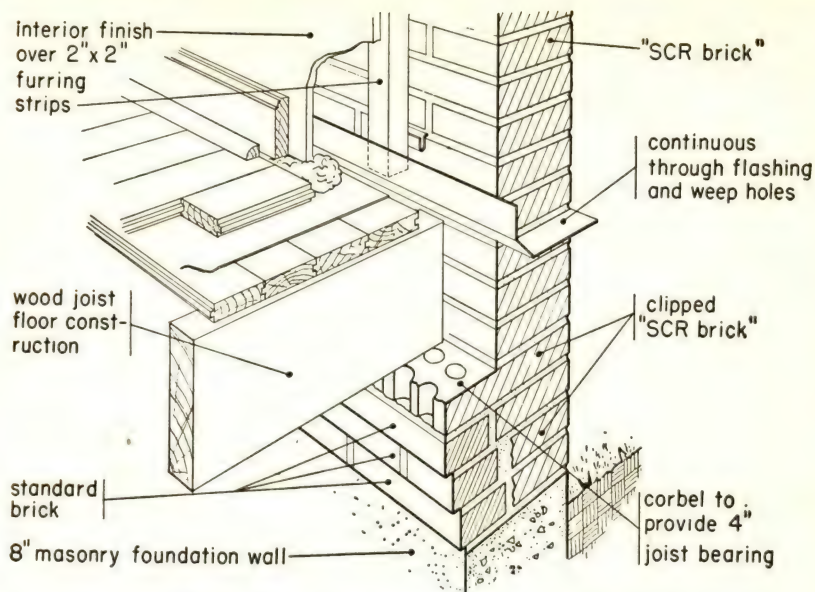
Fig. 8. Floor Joists Supported on Corbeled Wall
Courtesy of Structural Clay Products Institute

FURRING CLIP

2x2 FURRING

LATH AND PLASTER OR DRY WALL

FIN. FL.

WEEP HOLES 2'-0" O.C.

FLASHING

JOISTS 2x8's or 2x10's NOTCHED

"SCR BRICK"

CLIPPED "SCR BRICK" HEADERS

CONCRETE FOUNDATION

10"
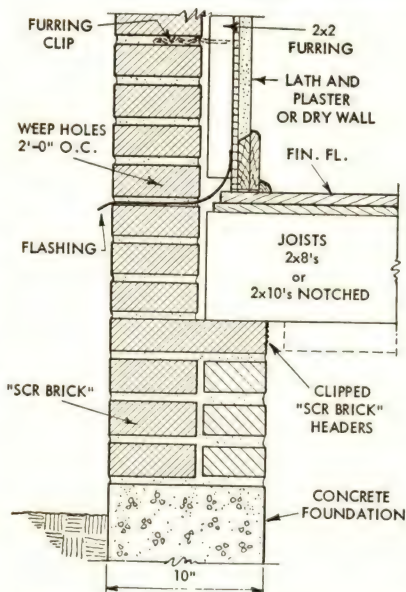
Fig. 9. Construction on 10" Foundation

FURRING CLIP

2x2 FURRING

LATH AND PLASTER OR DRY WALL

FIN. FL.

WEEP HOLES 2'-0" O.C.

FLASHING

JOISTS 2x8's OR 2x10's NOTCHED

"SCR BRICK"

CONCRETE FOUNDATION

12"
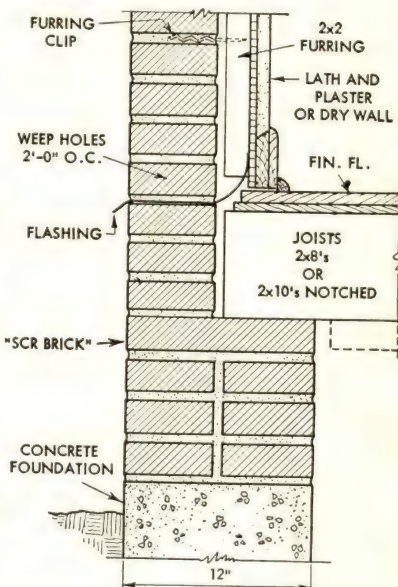
Fig. 10. Construction on 12" Foundation

case, the SCR brick are backed up from the grade line to the joist level
with masonry 4″ thick. On 12″ foundations, the same procedure may be
followed if the 2″ "shelf" on the foundation wall is not objectionable.
Otherwise, backup units 6″ thick may be used as shown in Fig. 10.
Whenever constructing walls two units in thickness, the two wythes of
masonry should be carefully bonded together with metal ties. It should
be borne in mind that the limitations upon the height of 6″ walls ap-
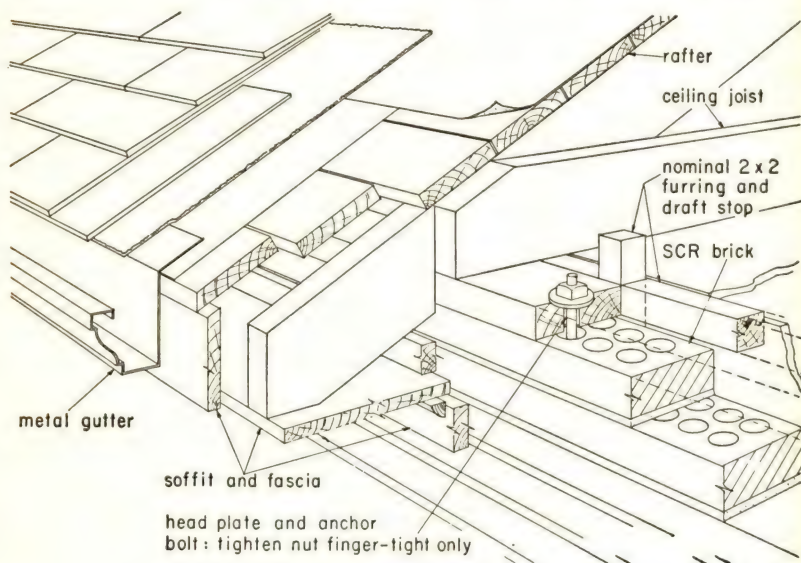
Fig. 11. Anchoring the Head Plate
Courtesy of Structural Clay Products Institute

plies only to that part of the construction that is actually only 6″ in
thickness.

Head Plate Anchorage. A continuous 2″ x 6″ head plate is an-
chored to the SCR brick wall by means of anchor bolts, in the manner
shown in Fig. 11. When the units are laid with stretcher bond, the core
holes line up and no cutting is necessary to locate the anchor bolts. The
depth to which the bolts must enter the wall is regulated by local codes,
but should never be less than three courses of brick. If ⅜″ bolts are
used, they should be spaced no more than four feet apart; ½″ bolts
may be eight feet apart. The bolts pass through the core holes and, by
staggering their positions, bowing of the head plate will be prevented.

The anchor bolt nuts are to be tightened with the fingers and a wrench should never be used on them. Since the furring strips are nailed to the head plate, it should extend about ¼″ beyond the inside edge of the wall, to properly line up with the strips.

Doors and Windows. Using SCR brick, lintels may be designed in several ways, as shown in Fig. 12. When reinforced brick lintels are used, care must be taken that the construction details have been ac-
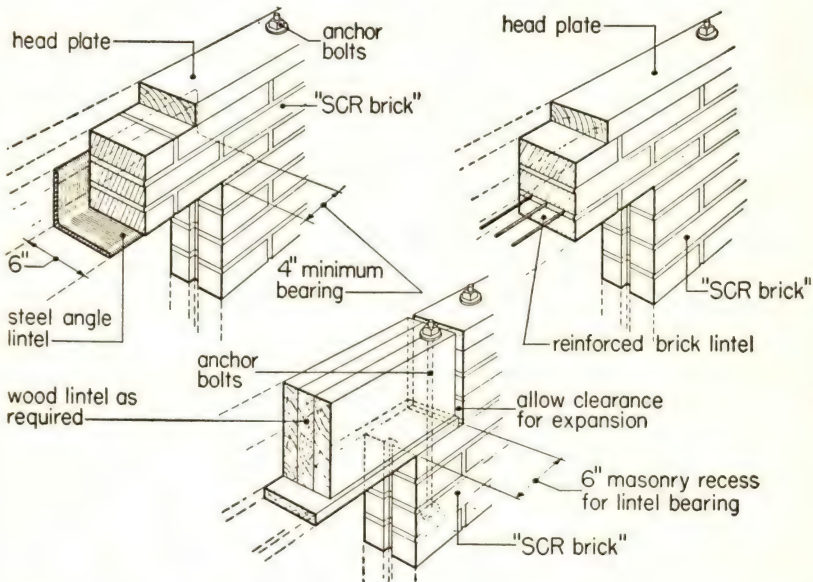
Fig. 12. Three Methods of Lintel Construction
Courtesy of Structural Clay Products Institute

curately computed to safely bear the load over the opening. Where steel lintels are used, the horizontal width must be 6 inches. In some cases it may be desirable to employ all frame construction above the height of the openings. Fig. 13 shows a residence designed in this fashion.

Installation of doors and windows in SCR walls raises no unique problems. Stock items can usually be selected that will not necessitate any unusual cutting of brick. The fin of a steel window frame fits into the jamb slot of the brick as shown in Fig. 14. Installation of a wood window frame is illustrated in Fig. 15, with the blind stop fitted into

Fig. 13. A One-Family Residence Constructed with SCR Brick
Courtesy of Structural Clay Products Institute

the brickwork and the frame anchored in the wall with a buck anchor. Proper calking will make either type of construction weathertight. Standard procedures in placing flashing should be followed.

Door construction details are similar and are illustrated in Fig. 16.
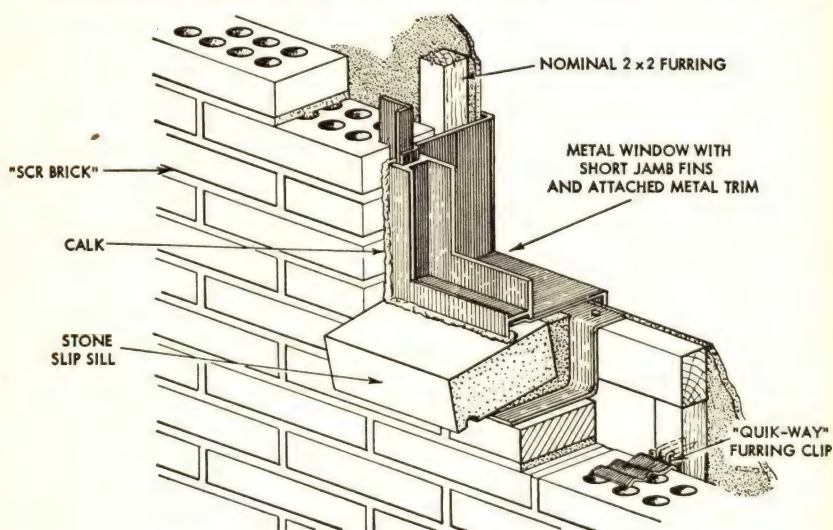
Fig. 14. Installation of Steel Window Frame

blocking

buck anchor

wood window with blocking secured to brickwork with corrugated buck anchors

nominal 2 x 2 furring

flashing nailed to top of sill blocking, corners cut back as shown.

SCR brick

standard brick

flashing extends 6" past jamb into brickwork
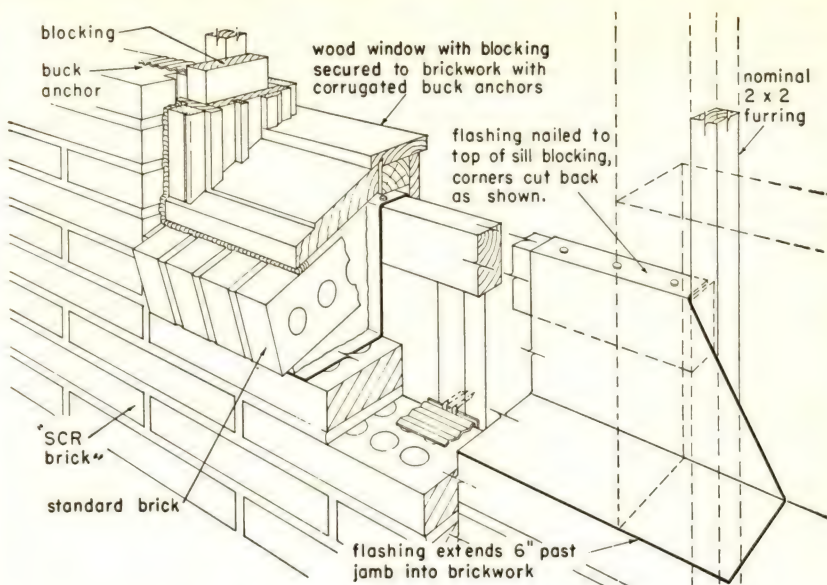
Fig. 15. Installation of Wood Window Frame
Courtesy of Structural Clay Products Institute

NOTE: LINTEL OMITTED FOR CLARITY

ROUGH BUCK BUILT INTO WALL WITH BUCK ANCHOR

NOMINAL 2x2 FURRING

CALK

WIND BREAK

FINISH DOOR FRAME SET INTO ROUGH BUCK AFTER COMPLETION OF BRICKWORK

BUCK ANCHOR

ROUGH BUCK

"SCR BRICK"
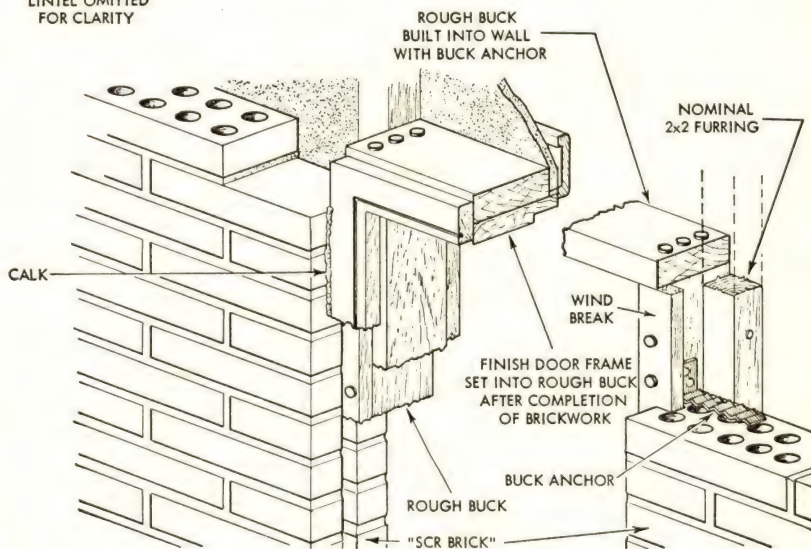
Fig. 16. Details of Door Frame Construction

A ¾" strip is fastened to the rough buck and installed in the slot of the brickwork. The addition of calking insures a positive weather stop to prevent the entrance of wind or water. The rough buck is securely held in place by anchor strips in the joints of the masonry. After completion of the brickwork, the finished door frame is set in position in the ordinary way.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. What the nominal size of an SCR brick is?
Answer. 2⅔" x 6" x 12 inches.

2. The best widths to plan doors and windows in SCR brick walls?
Answer. In multiples of 6" or 12", so only half-lengths will have to be cut.

3. What size furring strips are used on an SCR brick wall?
Answer. 2" x 2 inches.

4. How floor joists can be supported when building with SCR bricks?
Answer. By installing metal hangers or by corbeling. Joists cannot be framed into a 6" wall.

5. Whether the limitation on the height of a 6" wall applies to the overall height, regardless of thickness?
Answer. The limitation applies only to that part of a wall that is actually only 6" wide.

REVIEW QUESTIONS

1. What are the advantages of SCR brick?
2. What are the actual dimensions of an SCR brick?
3. What kind of bond is recommended for laying SCR brick?
4. What provisions are made to eliminate moisture on SCR brick?
5. What methods are used to accomodate a 6" brick wall to a 10" or 12" foundation?
6. How are head plates installed on an SCR brick wall?
7. Describe three methods of lintel design for SCR brick construction.

Maintenance, Repair, and Improvement

QUESTIONS CHAPTER XI WILL ANSWER FOR YOU

1. *What causes efflorescence and how can it be removed?*
2. *How are the most common stains removed from masonry?*
3. *How are cracks and defective joints repaired?*
4. *What measures can be taken to prevent dampness and flooding in basements?*
5. *What paints are satisfactory for use on exterior walls?*

INTRODUCTION TO CHAPTER XI

Sound masonry construction properly built with good materials possesses great durability. The most important factor in achieving satisfactory service is excellent craftsmanship; the usual cause of deterioration of masonry structures is poor workmanship. However, even the best construction will need occasional repair and upkeep to maintain it in a condition of good preservation and pleasing appearance.

A regular routine of periodical maintenance will correct any structural defects before extensive and costly repairs are needed. Thorough inspections will reveal points of potential failure that can be checked by preventive measures. The cost of eliminating conditions such as water penetration or flooding will be less than the total cost of combating the inconvenience and repairing the ultimate damage.

Any delay in remedying defects will inevitably increase the overall repair bill. The action of moisture and temperature changes may cause slight flaws to develop into widespread disintegration. A systematic maintenance routine is a wise investment because it protects property values. Neglected structures will depreciate rapidly.

The appearance of masonry is often marred by the presence of unsightly efflorescence. Also, masonry is subject to discoloration by a variety of stains. In this chapter you will learn how to correct these conditions.

There was a time when the original appearance of masonry was essentially inalterable. But with the development of paints expressly for masonry, color and brightness can be imparted to the drabbest surface. Judicious use of paints will beautify exteriors and render interiors more attractive and cheerful.

This chapter will tell you how to maintain masonry in a good state of repair and appearance. You will learn what corrective steps to employ. The removal of stains and discoloration is described. The preparation and application of various kinds of paints are discussed.

IMPORTANCE OF PERIODICAL INSPECTIONS

Regular inspections will save trouble and expense. If failure is discovered before it has resulted in extensive damage, the amount of repair work needed will be correspondingly less. Inspections should be conducted at established intervals and carried out in an orderly fashion. A good procedure is to begin with the basement and then to work up to walls, chimneys, etc.

Basements. Examine foundation walls for cracks and look for loose mortar in joints. Inspect floor for cracks or disintegration. Look for signs of leakage through walls or floor and determine whether there is leakage between the walls and floor.

Fig. 1. A Well-Maintained House Improved in Appearance by Painting
Courtesy of Masonry Building

The source of dampness in a basement may be determined by a simple test. Place a thin sheet of bright tin about 6″ square flatly against the damp wall. The tin may be secured in place with adhesive at the corners. If moisture collects on the visible surface in one hour, condensation is the cause. But if the metal remains dry, the dampness is the result of water penetration from without.

Exterior Walls. In masonry walls, look for cracks or broken bricks

or blocks, especially above door and window openings. Observe if joints need pointing. If a thin knife blade will pass between mortar and masonry units, repairs are needed. Note if there is efflorescence (moldy or white blotches or streaks) on the face of walls, particularly below window sills and near downspouts.

Stucco. Failure of stucco usually appears in the form of cracks, chipping off, or falling out of particles. Such evidence appears most often over doors and windows and near the ground. These defects are most readily apparent after a rain, when moisture penetration becomes visible.

Cracks may appear because of uneven settling of the building. Stucco on masonry, especially around chimneys, is subject to cracking because of the difference between the rates of expansion and contraction of the materials.

Chimneys. Chimneys should be carefully examined for defective joints. Crumbling of mortar may leave openings into the flue, presenting a serious fire hazard. If the entire chimney displays extensive failure of joints it should be dismantled and completely rebuilt.

Openings. Check the calking around all doors and windows to ascertain if it satisfactorily seals up all spaces. Inspect the condition of all flashing and determine if more should be installed.

Inspection Check List. To insure that nothing is overlooked a check list similar to the following should be drawn up:

1. Basement walls for cracks or faulty mortar joints.
2. Basement walls and floors for leaks that might require waterproofing or drainage.
3. Basement floor for cracks or deterioration.
4. Grading around foundation for proper drainage.
5. Masonry walls for cracks or broken areas.
6. Mortar joints to see if pointing is needed.
7. Walls for leakage that may require dampproofing.
8. Masonry walls for efflorescence, scum, or stains.
9. Painted surfaces to see if blistering, cracking, or peeling has occurred and if repainting is necessary.
10. Window caps to see if new flashing or repair of joints is needed.
11. Eaves or tops of walls for leakage to see if repairs or copings are needed.
12. Porch walls and floors for defects.
13. Chimneys for defects, and to see whether pointing or replacement is necessary.
14. Need for chimney caps or pots.

15. Cracks between chimneys and side walls.
16. Fireplace.
17. Stucco walls for cracks, discoloration, or damaged portions.

MAINTENANCE

Efflorescence. Efflorescence is the deposit of crystallized salts on the outer surface of masonry. The deposit is usually white; but it may be another color, depending upon the color of the salts and impurities in the material. The salts are dissolved by moisture in the wall and the solution seeps to the outside, where the water evaporates, leaving a salt deposit as shown in Fig. 2.

Because of the moisture in mortar and large amounts of salts in new materials, efflorescence is most common on new masonry. With time the salts are eliminated and accumulation ceases. Efflorescence is usually found where a wall is subject to frequent wetting from gutters and downspouts, or window sills and copings. Excessive rainfall may bring about the condition.

PREVENTION. Because efflorescence results from the evaporation of absorbed water, the difficulty can be alleviated by preventive measures. Gutters and downspouts should be checked and any leaks repaired. Window sills and copings should have drip grooves to keep water away from the wall.

Where the condition is extremely bad, a colorless waterproofing compound which checks absorption may be applied to the exterior surface of the wall.

Efflorescence is often caused on exterior surfaces of masonry chimneys by water vapors carried up the interior of the flue, especially where gas or oil is used as fuel, and condensing on the cool, smooth flue lining near the top of the chimney. The condensation is absorbed by the terra-cotta flue lining and the surrounding masonry, carried by capillary action to the exterior, where the water evaporates, leaving a deposit of any soluble salts it may have picked up from the masonry or that may have been present in the vapors.

It is of no use to waterproof the exterior of a chimney in such cases. An asphalt coating on the inside of the upper portion of the flue or flues will often be the best preventive.

REMOVAL. Efflorescence diminishes as a structure becomes older.

It may sometimes be satisfactorily controlled by brushing vigorously with a stiff fiber or wire brush.

To remove more objectionable deposits, use a wash of 1 part muriatic acid and 6 to 10 parts of water. *Pour the acid slowly into the water; never pour water into the acid.* The acid is harmful to the skin and eyes. While preparing and using the solution, wear goggles and rubber gloves.

Using a fiber brush, scrub the efflorescent spots thoroughly with the acid solution, avoiding mortar joints. Wash the surface of the wall with clear water after completion. Finally, it is best to wash the surface with a solution consisting of 1 pint of ammonia in 2 gallons of water. This will remove all traces of the acid.

It may be necessary to repeat the treatment until all of the soluble salts have been eliminated from the masonry.

Muriatic acid should never be used on concrete masonry. Muriatic acid softens cement for ease of removal from the surface of a

Fig. 2. Efflorescence on a Recently Constructed Brick Wall
Courtesy of Masonry Building

hard burned clay product. When used on a concrete product it will soften and remove the hardened cement paste from the surface and so destroy the finish and/or texture, which would permit a greater water penetration.

Concrete products made with cinders or slag as an aggregate contain particles of iron which will rust and stain the surface if the cement paste is removed from the surface by an acid solution. The iron rust will also expand, causing spalling of the unit.

Before an acid solution is applied to any brickwork, the brickwork should be thoroughly wet with clean water. This will fill the pores of the brick and of the mortar and prevent the absorption of the acid solution, which could cause stains to appear after drying.

A good rule to follow when using a solution of muriatic acid is always to wet any material to be cleaned with clean water before applying the acid solution and to follow up with a thorough rinsing with more clean water.

If any stone is used as a part of the wall such as sills, coping or other trim, the stone must be kept saturated with clean water. If the acid solution penetrates the stone it will usually discolor, particularly so if the stone contains any iron oxides.

Stains. Almost any stain can be removed from masonry but old, stubborn stains may require considerable persistence to eradicate. In the case of stains of unknown origin, experimentation may be necessary to discover the proper agent. Many chemicals can be applied to masonry without ill effects. However, acids or chemicals producing an acid reaction should be avoided, because they tend to roughen the surface after a short time.

To remove stains that have penetrated the material, it may be necessary to apply a poultice. This is made by mixing the active ingredients with a fine inert powder so as to form a paste. The paste is applied in a thick layer and covered with cotton batting. On walls the poultice is then covered with a board that is braced in position.

IRON STAINS. Iron stains usually have a rusty appearance and the source can often be traced to rusting iron or steel on the building. Masonry may be stained by the iron in water used for curing a wall. This condition may be improved by mopping the area with a solution containing 1 pound of oxalic acid powder to a gallon of water. The surface should be scrubbed and then rinsed with clear water after 2 or 3 hours. Bad spots may yield to a second application.

Darker stains require other measures. In 6 parts of water dissolve 1 part of sodium citrate and mix with an equal volume of glycerin. Use this liquid to form a paste with whiting stiff enough to adhere in a thick layer. Apply to the surface with a putty knife or trowel. The application will dry in a few days and should be softened with additional liquid or be replaced by a new layer. This process may act too slowly to be practical on bad stains. Faster results may be achieved by using ammonium citrate instead of sodium citrate but it may slightly mar polished surfaces.

For very deep and dark iron stains, sodium hydrosulphite produces better results. First dissolve 1 part of sodium citrate crystals in 6 parts of water. Soak the surface by dipping cotton batting or white cloth into the solution and applying it to the stains for 10 or 15 minutes. Cover flat surfaces with a thin layer of hydrosulphite crystals, moisten with water, and apply a thick paste of whiting mixed with water.

For walls place the paste on a plasterer's trowel, cover with a layer of crystals, moisten, and apply to the stained area. After one hour, remove the application; if it is left on longer it may blacken the area. A stain that is not completely removed may be treated again with new materials. After the discoloration has disappeared, rinse the surface with clear water.

COPPER, BRONZE, AND ALUMINUM STAINS. Copper and bronze stains are usually green, but sometimes may be brown. Mix 1 part ammonium chloride (sal ammoniac) with 4 parts of powdered talc. Add ammonia water to form a paste. Apply the mixture over the stain and allow it to dry. Stains that have been accumulating for several years may require a number of treatments. Aluminum chloride may be substituted for ammonium chloride.

Aluminum stains leave a white deposit which may be removed by scrubbing with a 10 to 20 percent solution of muriatic acid. Use a weaker solution on colored masonry surfaces.

SMOKE AND FIRE STAINS. Remove the surface deposit by scouring with powdered pumice or a grit scrubbing powder. Soak several layers of flannel cloth in the solution and apply over the stained area. Use a slab of concrete or glass to hold the cloth firmly in place. Resaturate the cloth until the stain disappears.

OIL STAINS. Oil spilled on concrete should be wiped off immediately. If the area is then covered with fuller's earth or other dry material such as hydrated lime, whiting, or cement the oil will be absorbed. Oil on the surface may sometimes be removed by scrubbing with benzine or gasoline.

Special treatment is required to eliminate neglected areas because oil readily penetrates some masonry. Prepare a mixture of equal parts of acetone and amyl acetate. Soak a flannel pad in the solution and apply it to the affected surface. Hold the cloth securely in place with a slab of concrete or piece of glass. Saturate the cloth until the stain

is eradicated. A glass covering over the patch drives the oil into the masonry, whereas dry concrete absorbs it.

TOBACCO STAINS. Some tobacco stains may be removed by a poultice made from a grit scrubbing powder. Use hot water to produce a mixture of mortar consistency. Apply a ½″ layer and allow it to dry. Repeated applications are usually needed.

A more effective method that is also useful on other stains employs trisodium phosphate. Dissolve 2 pounds of the crystals in 1 gallon of hot water. Thoroughly mix 12 ounces of chlorinated lime with water to form a smooth paste. Pour the solution and paste into a 2-gallon jar and fill with water. Stir the mixture, cover and allow the lime to settle. Use the liquid to make a thick paste with powdered talc. Apply as a poultice and scrape off after dry. The mixture is a strong corrosive and bleaching agent. It should not be dropped on fabrics or metal fixtures.

INK STAINS. The correct procedure for removing ink stains depends upon the composition of the ink. The acid in ordinary writing inks may cause etching of concrete masonry. Prepare a thick paste by mixing whiting in a strong solution of sodium perborate and hot water. Apply a poultice ¼″ thick and allow it to dry. If blue color remains, repeat the treatment; if a brown stain is left, treat it with sodium citrate as described for iron stains.

Stains caused by indelible ink or bright colored ink containing synthetic dyes may yield to the foregoing treatment. Often they can be removed by applying cotton batting soaked in ammonia water or javelle water. Javelle water may also be mixed with whiting and used as a poultice. A paste formed by adding water to a mixture consisting of equal parts of whiting and chlorinated lime can be used as a poultice.

Ammonia water must be used to remove stains left by inks containing prussian blue. Black stains caused by indelible ink usually require several treatments with a bandage wetted in ammonia water.

MISCELLANEOUS STAINS. Discoloration caused by decaying wood is easily identified by its dark color. The treatment outlined for smoke stains is effective. The action may be hastened by first scrubbing the surface with a solution of glycerin diluted with four parts of water.

A glycerin solution is also effective on coffee stains. Javelle water, or the solution specified for fire stains may also be used.

Iodine stains gradually disappear with time. They may be quickly removed by applying alcohol and covering with talcum powder or whiting. On walls, apply alcohol and cover with a paste made from talcum and alcohol.

Perspiration may leave a yellow or brown stain on concrete. Follow the same procedure given for fire stains. Repeat as often as needed.

Cleaning Stucco. Stucco can be renovated by painting with a cement-water paint. Hair-line cracks need not be repaired as the paint will fill them. Chipping out and refilling a fine crack will only make the flaw more conspicuous. Before applying the paint, clean the old surface by washing it with clear water and then thoroughly scrubbing with a solution of 1 part of muriatic acid in 6 parts of water. Rinse off all traces of the acid solution with clear water.

REPAIR

Cracks and Defective Joints. Cracks or defective joints are subject to rapid deterioration because of the effects of weather. Mortar joints are more vulnerable than cracks in concrete walls.

Water does not penetrate mortar or building units, but passes through the wall between the units and the mortar. Improper bonding is generally caused by faulty workmanship when the wall is laid up. The original bond may be unsatisfactory or the workman may disturb the position of a unit after it is laid, breaking the bond.

If the absorption rate of the masonry is too high or the water retentivity of the mortar too low, improper bonding will also result.

Cracking or failure of mortar joints can also result from settling stresses imposed by uneven weight distribution or weakening caused by underground springs or damp soil.

A certain amount of joint failure and cracking is to be expected in any masonry structure. Water penetration should be anticipated in the original construction by backplastering and the installation of necessary flashing and drips. Cracking of concrete block walls can be prevented by providing adequate control joints.

After crevices have appeared in masonry they will steadily become worse unless repaired on time. Alternating expansion and contraction of the structure tends to open up and extend the cracks. Water entering the wall freezes and widens the openings.

Repair of Cracks in Exterior Concrete Masonry Walls. Unless it is absolutely necessary to exclude water, do not attempt to repair cracks as soon as they appear. The cracking may progress for some time. Cracks in a new wall should not be filled until a year after completion of the work.

Cracks should be repaired with a material that matches the original construction in color. Do not use plastic or bituminous compounds, which result in an unsightly appearance. Moisten old concrete or mortar around the crack and keep the new material damp for two or three days. Tool mortar joints to match the surrounding areas. After repair material has set slightly, roughen it with a piece of damp burlap to produce a texture like that of the blocks. Repairs on painted walls should be touched up to match the original shade.

SMALL CRACKS. Cracks up to ⅛″ can be cleaned with a wire brush or a thin blade. Make a heavy paste from dry cement-paint and a little water. Use a stiff bristle brush or putty knife to force the paste into the opening. As a substitute for cement-paint, a paste may be made from portland cement mixed with 2 parts of very fine sand.

LARGE CRACKS. Cracks over ⅛″ wide should be raked out to provide a firm key for the mortar. Form an inverted **V**-shaped groove at least ½″ deep. Use 1 part cement and 2 parts of sand to prepare a mortar with the consistency of damp earth. Allow the mortar to stand for about an hour and retemper it without water immediately before using. Tamp the mixture solidly into the crack to insure a good bond. To control drying, it is sometimes desirable to add an expansive agent. Aluminum powder or expansive cement are satisfactory, but admixtures containing iron should not be used for they may cause staining.
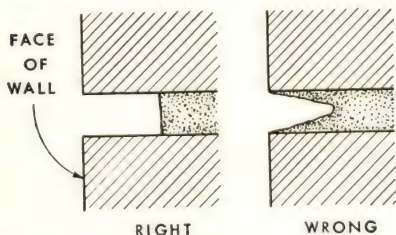
Fig. 3. Right and Wrong Methods of Preparing Joints for Tuckpointing

Tuckpointing. Whenever the joints of a brick wall have deteriorated extensively, repointing is necessary. Remove the loose mortar from defective joints to a depth of at least ½″ as shown in Fig. 3. Do not disturb sound mortar, but remove all that is loose or crumbling. Cut out the joints

clean so as to leave a square bottom. Wire-brush the openings and wash out with a stream of water. Do not begin to repoint immediately, but allow the wall to dry partially. If repairs are not completed at once, again dampen the wall slightly before applying new mortar.

If repointing is being done as a maintenance measure, only those joints that are visibly defective should be cleaned and filled with mortar. However, if the work is being done to correct the entrance of water, all joints should be repointed regardless of their apparent condition.

Bricks that are loose, broken, or badly spalled must be replaced with matching units. Remove all old mortar from the opening. Apply mortar in the cavity and to the brick. Force the brick into place and pack the joints solidly with mortar.

The preferred method for tuckpointing is to apply the mortar in layers. First pack mortar into deep cuts to bring them up to the average depth of the other joints. The joints should then be filled by tooling mortar firmly into place in layers not exceeding ¾″ in thickness. Allow each layer to set until "thumbprint" hard and roughen the surface before pressing in the next layer. Tamping the mortar in in this fashion is recommended for a successful job. The procedure is intended to bring the pointing mortar to the same condition as the old material that has already gone through the hardening and shrinking stages.

The composition and preparation of mortar for tuckpointing is especially important. A satisfactory mix for ordinary work can be made from 1 part portland cement with 1 to 1¼ parts of lime. Use enough sand in mixing so that the mortar is stiff enough to adhere to the pointing trowel. It is best to make the mortar slightly wetter than desired. Before using, allow it to set for one-half hour and then re-temper without adding more water. Prepare the mortar in small batches and do not use it if it becomes dry or granular.

Cracks in Stucco. Large cracks should be chipped out in the shape of an inverted **V**, so that the new material will remain firmly in place. Clean the area and dampen before new material is applied.

For pointing, a mixture identical to the original material should be used. If this is not known use a mixture of 1 part cement, 3 parts sand, plus ⅒ part hydrated lime. Add any mineral pigments needed for coloring. Use enough water to make a dry mixture with the con-

sistency of putty. Tamp the material firmly into the crack and keep it damp for several days. If cracks appear in the new work, the entire surface may have to be covered with a cement-water paint.

IMPROVEMENT

Water Penetration. Dampness usually comes from one or more of four sources: (1) leakage of drainage water from roofs and adjoining surfaces, (2) penetration of wind-driven rain into walls, (3) condensation of moisture within exterior walls or on their interior surfaces, (4) rise of ground water by means of capillary action.

Before deciding on corrective measures, it is necessary carefully to determine where water enters. Moisture may appear on the inside of a wall far below the point at which it enters. Flashings must be checked to make sure that they are designed properly to exclude water.

VAPOR BARRIERS. Moisture may accumulate when warm vapors from cooking, washing, or other sources condense on the cold inside surfaces of masonry. This moisture can enter the wall and cause future trouble. The best remedy for this condition is to provide a vapor barrier on the inside of the wall. Furring strips are installed and a plaster or wallboard surface applied over them. The dead air space resulting constitutes an insulation that will keep the inner surface of the masonry warm and prevent condensation. In severe climates it may be desirable to fill the space with insulating material.

When furring is installed old trim must be removed. Door and window frames should be blocked and cased out to the plane of the new interior surface. Then restore the trim.

GROUTING. Joints that are sound enough not to require repointing may still allow some rain to enter and cause dampness on the inside of exposed walls. On smooth masonry the joints may be made impervious to rain by grouting. The mixture should consist of equal parts of portland cement and sand with enough water worked in to form a grout with the consistency of thick cream.

Moisten the exterior joints and scrub in the grout with a stiff fiber brush. Remove the excess from the face of the masonry units without disturbing the deposit in the joints. This treatment is not recommended for walls constructed from rough-textured brick.

Wet Basements. Wetness in a basement may take the form of moisture on surfaces of the walls or the penetration of water in large quantities, resulting in flooding.

CONDENSATION. If dampness in a basement is caused by condensation, it may be controlled by applying proper insulation to cold water pipes. Improving the ventilation will also help to relieve the problem.

Humidity may be reduced by placing several containers of calcium chloride in the basement. As liquid collects in the containers it must be removed. In some cases it may be advisable to install a mechanical dehumidifier. The apparatus draws moisture from the air and also gives off a small amount of heat which reduces condensation.

INTERIOR DAMPPROOFING. Dampproofing on the interior of a foundation wall is generally ineffective. The best measure is to apply a thick layer of mortar. A mortar made of 1 part cement, 3 parts of sand, and 10% of lime should be used. The lime in the mortar will help to waterproof the wall and will make the mortar more plastic, and so easier to apply. Many of the masonry cements made by the leading cement companies are also very good for this purpose, in place of the portland cement and lime. Such cements usually contain plasticizers and water repellents ground in, in proper proportions, by the mills. The mortar should be applied when no leakage is taking place. After application the finish coat should be kept damp for a week after it has set to enhance its effectiveness.

Where an active leak exists, use a high-early-strength portland cement and add calcium chloride up to 5% of the weight of cement. Hold the putty in place with a board until it is hard.

Condensation will not, as a rule, form on a rough surface, so what is known as a *sand finish* is best for interior basement walls.

CRACKS AND DEFECTIVE JOINTS. For repairing basement walls a mixture of 1 part cement to 2½ or 3 parts sand is best for ordinary conditions. In very damp basements a 1:2 mixture may be desirable, because a larger proportion of cement is needed under moist conditions. Only enough water should be used to make a fairly dry mortar when thoroughly mixed.

Chip out cracks to form an inverted wedge or **V** shape with rough edges. Remove all loose material from defective mortar joints. Brush

out the opening thoroughly and dampen it before new mortar is applied, so that moisture will not be absorbed from the mixture.

Tamp in the mortar thoroughly to form a complete bond with all surfaces. After the material has set, keep it damp for several days to assist hardening.

Leaks may occur at the boundary between the basement floor and the walls. Chip out a groove along the edge of the floor 1½″ to 2″

Fig. 4. Filling Joint between Basement Floor and Wall with Hot Bituminous Material
Courtesy of Portland Cement Association
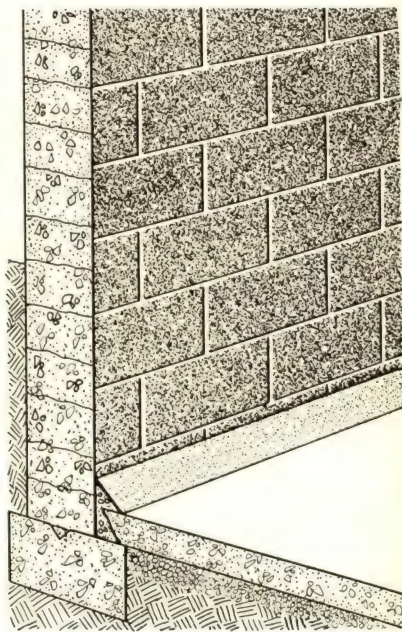
Fig. 5. A Cement Cove Built Up at the Intersection of a Basement Floor and Wall

deep. Make the cut wider at the bottom to achieve a secure key. Fill the space with hot tar as shown in Fig. 4. The bitumastic may be mixed with sand. Or the groove may also be filled with a quick-setting waterproof cement. The cement should be built up to form a cove along the intersection as illustrated in Fig. 5.

DRAINAGE. Entrance of moisture into a basement may sometimes be remedied by diverting the water from downspouts away from the

building. In some cases site or construction may necessitate provisions for draining water away from the foundation.

Surface. Water may be kept away from walls by filling with earth to provide a sloping grade extending 8′ or 10′ from the wall. This slope should have a good, dense growth of grass. A 2′ or 3′ concrete water shed may be laid up to the basement wall with a slight slope away from the building.

Surface water may be turned away by a concrete gutter surrounding the building and draining to a low spot. This gutter should be bonded to the wall by cleaning, roughening, and wetting the area of contact. The gutter should be at least 2′ wide overall, with the outer ledge about 5″ wide. The outer edge of the trough ought to be about 4″ deep.

Foundation. In damp locations or other places where the subsoil contains much water, it is advisable to install a drain around the walls to carry off the water before it can enter the basement. A trench is dug next to the wall below the depth of the basement floor, but not below the footing. Drainage tile can then be installed as described in Chapter III. The tile should be at least 3″ but preferably 4″ in diameter. Before refilling the trench, waterproof the exterior of the masonry in the manner discussed on pages 123–130.

FLOODING. Occasional severe flooding in a basement is sometimes most effectively and economically dealt with by installing an electric pump. A sump is provided in the floor and the pump automatically operates when water reaches a certain level.

Painting. There are four types of paint in general use for masonry walls: (1) cement-water paints, (2) resin-emulsion paints, (3) oil paints, (4) rubber-base paints. Each of these is adapted to a particular kind of service and varying application procedures must be followed. These paints are not suitable for floors subject to abrasive wear.

INTERIOR WALLS. Generally dry interior masonry walls above grade may be painted in the same manner as plaster surfaces. Where the wall contains portland cement it is necessary to take precautions against alkali action. Rubber-base paints may be used as alkali-resistant primers.

Any dry basement wall or wall above grade may be decorated with an exterior masonry wall paint. Damp basement walls can be most

successfully covered with a cement-water paint in the same manner as an exterior wall.

EXTERIOR WALLS.   General instructions for the use of masonry paints are given in the following paragraphs. In every case, manufacturers' directions for the preparation and application of paints should be carried out.

Cement-Water Paints.   Cement-water paints are available in a variety of colors. They are sold in prepared powder form and need only be mixed with water to be ready for use. They consist mainly of portland cement or cement and lime. The paint selected should meet Federal Specification TT-P21 and should contain no less cement than 65% of the total weight.

Fig. 6.   Moistening a Wall before Applying Cement-Water Paint
Courtesy of Portland Cement Association

Cement-water paints enhance the appearance of masonry structures and improve weathertightness. These paints are especially suitable for use on new or damp surfaces. They may be applied to any concrete masonry, common brick, cinder blocks, stucco, soft tile, or any clean surface having some absorption properties. They are not suitable for enameled, glazed, or vitrified surfaces. Cement-water paints should not be applied to interior surfaces in an attempt to stop leaks caused by severe water pressure from without.

Before application remove all dust, dirt, and efflorescence from the surface, by brushing followed by washing with clean water. Any previous coating of organic paint must be completely removed. Sandblasting is the best method to accomplish this. Old coatings of cement-water paint that are not flaking need not be removed, but should be brushed to provide a uniform surface.

Not more than one hour before painting, the wall should be dampened. The best method is to use a fine spray nozzle (Fig. 6), directing it at each part of the surface several times, a few seconds each time.

If the wall dries rapidly, it should be dampened again immediately before painting, so that it is moist but not dripping.

Mix the paint thoroughly in accordance with the manufacturer's instructions and stir it frequently while being used. Do not apply to frosty surfaces or when the temperature may drop below 40°F within 48 hours.

An ordinary paint brush is usually not satisfactory for applying cement-water paints; a brush with short, stiff bristles not over 2″ long,
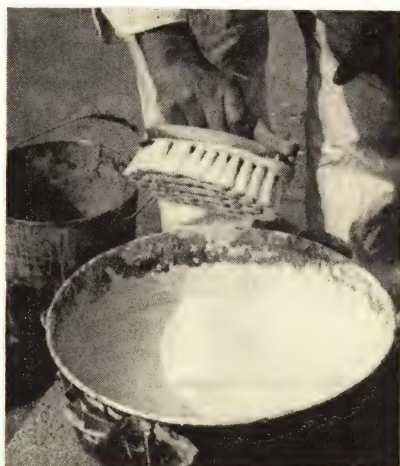
Fig. 7. Brush Used for Applying Cement-Water Paint

Fig. 8. Cement-Water Paint Should Be Applied to Mortar Joints First

Courtesy of Portland Cement Association

such as a new scrub brush, should be used, as illustrated in Fig. 7. Two coats should be applied allowing at least 24 hours for the first to dry. Paint the mortar joints before the masonry units first as shown in Fig. 8. Before the second coat is applied, the surface should again be moistened slightly.

After the paint has set, which generally requires 6 to 12 hours, moisten the wall with a fine spray two or three times a day. This should be done for two days after the final coat and also between coats.

Before applying cement-water paint to new masonry, loose material

should be brushed off and any form oil removed by cleaning with a solution consisting of 1 part lye in 5 parts of water.

Two-tone effects may be achieved by using a second coat different in color from the first. The two colors should harmonize. The second coat is applied lightly to high spots only, avoiding depressions. A mottled effect may be produced by rubbing off part of the second coat. When a particular color effect is desired, sample panels should be painted first.

Because of its durability, cement-water paint makes an excellent undercoat over which to apply an oil-base, resin-emulsion, or rubber-base paint for improved appearance. Cement-water paint should be allowed to age two weeks before applying a resin-emulsion paint and three months before an oil paint is applied.

Resin-Emulsion Paints.   Resin-emulsion paints come in paste form and must be thinned with water. They should be mixed in clean metal containers, in accordance with manufacturers' instructions.

Resin-emulsion paints may be used on most porous masonry surfaces. Before application, the surface must be thoroughly cleaned. Glossy areas should be rubbed with sandpaper and all grease spots must be removed. Wash the surface with water containing about 2 ounces of trisodium phosphate to the gallon and rinse with clear water.

A brush or spray may be used to apply resin-emulsion paints. The temperature should be above 40°F when painting. Open-textured masonry may be primed with a cement-water paint containing sand. Two coats of resin-emulsion paint should be applied, allowing the first coat to dry six to eight hours. Immediately after using, wash brushes and spray guns with warm soapy water.

Oil Paints.   Ready mixed oil paints for masonry contain weather-resistant pigments. Two coats are needed for adequate covering and durability.

It is imperative that oil paints be applied only to clean, dry surfaces. All loose areas of previous coverings must be removed. New walls should not be painted for three months to a year after construction, depending upon the characteristics and weather conditions. Do not apply oil paints when the temperature is below 50°F or during humid weather. Avoid application during early morning or late after-

noon when condensation may occur. Measures should be taken to insure that moisture does not enter the wall and damage the coating from underneath.

Rubber-Base Paints.   Rubber-base paints are of two types: the rubber-solution and rubber-emulsion types. They may be brushed or sprayed on dry or slightly damp walls. They are useful as sealing coatings or primers under resin-emulsion or oil-base paints.

Fig. 9. Whitewash Is Simple to Prepare and Apply
Courtesy of National Lime Association

Surfaces to be painted must be clean and free from all loose material. Rubber-emulsion paints may be applied over sound oil paints, but rubber-solution paints may not.

The first coat should usually be thinned with the thinner specified by the manufacturer. Rubber-base paints should be applied like enamel. At least 18 hours should elapse between coats. Because the paint sets rapidly it is desirable to work in shade. Clean brushes and spray guns with thinner immediately after use.

WHITEWASH AND COLD-WATER PAINTS.   Whitewash is the cheapest covering and is easy to apply. It has the advantage of adding brightness to a dark space. Whitewash also reduces odors and promotes sanitation around farm buildings and other structures.

Preparation. Whitewash can be made with hydrated lime but a better paint results when lime paste is used. Eight gallons of paste can be made by slaking 50 pounds of hydrated lime in 6 gallons of water. Keep the paste in a loosely covered container for several days. A refined commercial hydrated lime is preferable to an unrefined hydrate. This is especially important if the whitewash is to be applied with a pressure gun. Otherwise, it is essential to strain the paste through a fine screen. All lime producers today furnish an *auto-claved* or high-pressure hydrated lime that does not require soaking but is ready for immediate use.

Sufficient water must be added to produce a thin, milky liquid. Although lime alone makes a satisfactory whitewash for some applications, better results are usually obtained when other substances are added to the mixture.

Soak 5 pounds of casein in 2 gallons of hot water until thoroughly softened. Dissolve 3 pounds of trisodium phosphate in 1 gallon of water and stir into the casein. Add 3 pints of formaldehyde to 3 gallons of water. After the lime paste and casein solution have cooled, stir the casein into the lime. When ready to apply, slowly add the formaldehyde solution to the mixture. Stir constantly and thoroughly to produce a smooth paint. When properly prepared and applied, this formula produces excellent results. Do not prepare more than can be used in one day, as it may deteriorate.

For many purposes a simple formula may give satisfactory results. Make a dry mix from 25 pounds of *white* portland cement and 25 pounds of hydrated lime. Stirring in about 8 gallons of water will result in a thick mixture. Continue to thin until the whitewash has the consistency of heavy cream. Prepare only enough at one time to last for a few hours.

This formula will be improved by the addition of calcium chloride. Dissolve 1 to 2 pounds of calcium chloride in a small amount of water and add to the whitewash just before using.

A low-cost and usually very satisfactory whitewash can be made with an auto-claved lime, household salt and a few drops of bluing, such as is used in the home laundry. Add lime to water until it is the consistency of thinned paint, salt with one cupful of salt per 12-quart pail, add a teaspoonful of bluing, stir well, and apply to pre-dampened

surface with a large brush. (Bluing is not necessary, but it does make whitewash appear whiter.)

When mixing lime or lime and cement with water for whitewash or paint, add the dry powder to the water a little at a time. This makes mixing easier and avoids lumping. After mixing, keep the mixture stirred to prevent separation or settling.

Application. The surface should be clean and free of any previous coatings. Use a good, large brush and apply the whitewash quickly and evenly. The mixture should be thin enough so that the surface shows through the wet coating. It will then dry opaque as shown in Fig. 10.

A pressure spray or paint gun is the best means for applying white-
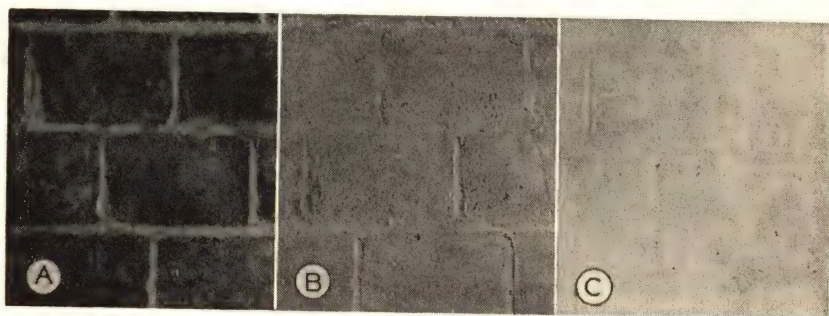
Fig. 10. Cinder Block Wall Dampened for Whitewashing, (A), Appearance of Wall Immediately after Application of Whitewash, (B), and the Same Wall after Drying, (C)
Courtesy of National Lime Association

wash. However, if such a device is used, the whitewash must be strained before being used to remove lumps that might clog the apparatus.

Cold-Water Paints. Cold-water paints are powdered preparations that are mixed with water. They contain casein, hydrated lime, or other materials. They are useful for economically renewing surface applications periodically or to freshen color. They are generally not recommended for outdoor service or under damp conditions.

Coloring. Pigments may be added to cold-water paints or the whitewash formulas previously discussed. The pigments used must not cause a chemical reaction with lime and they must not be soluble in water.

It is essential that the color be thoroughly mixed into the solution. The amount used will depend upon the shade desired. It is advisable

to apply a small test sample and allow it to dry before mixing a large quantity for a job.

CHECKING ON YOUR KNOWLEDGE

The following questions and answers and review questions give you the opportunity to check up on yourself. If you have read the chapter carefully, you should be able to answer the questions without referring to the answers. If you have any difficulty, read the chapter over once more so that you have the information well in mind before you go on with your reading.

DO YOU KNOW

1. How to determine whether repairs to masonry construction are needed?

Answer. By conducting periodic and systematic inspections.

2. When mortar joints require repairs?

Answer. If a thin knife blade will pass between the mortar and the masonry units.

3. Where is efflorescence most likely to occur?

Answer. On new construction or surfaces exposed to water.

4. How should the wash for removing efflorescence be mixed?

Answer. Always pour the muriatic acid slowly into water.

5. What procedure is used to remove stubborn stains?

Answer. Prepare a paste with the specified agent, apply it to the stain, and cover with cotton batting held firmly in place.

6. What should be done when oil is spilled on masonry?

Answer. Immediately wipe it off and cover the spot with fuller's earth or other absorbent material.

7. When cracks in new masonry should be repaired?

Answer. After sufficient time has elapsed for the cracking to cease, or at least a year unless there is serious water penetration.

8. What is the best method for tuckpointing joints?

Answer. Tool the new mortar firmly into place in layers. Allow each layer to set slightly and roughen the surface before applying the next layer.

9. What purpose a vapor barrier serves?

Answer. It creates a dead air space which serves as an insulating layer that prevents condensation of moisture on the interior of walls.

10. What kind of paint may be successfully applied to new or damp masonry?

Answer. Cement-water paint.

REVIEW QUESTIONS

1. What is the most common cause of deterioration of masonry construction?

2. How can the source of dampness in a basement be determined?

3. What causes efflorescence?

4. What solution can be used to remove efflorescence?

5. How may bronze or copper stains be identified?

6. What causes cracks or failure of mortar joints?
7. When should all mortar joints in a wall be repointed?
8. From what four sources can dampness originate?
9. Name the paints that may be successfully used on exterior walls.
10. What are the advantages of whitewash?

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